THE USE OF CHLORPYRIFOS TO CONTROL AMERICAN BOLLWORM 
(HELICOVERPA ARMIGERA) IN ORANGES (CITRUS SINENSIS L.) IN THE 
EASTERN CAPE PROVINCE OF SOUTH AFRICA

by

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UNIVERSITY OF SOUTH AFRICA

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JOINT SUPERVISOR : MS M M LEBUSA MOLAPO

FEBRUARY 2011
Declaration of originality

I declare that THE USE OF CHLORPYRIFOS TO CONTROL AMERICAN BOLLWORM
(HELCOVERPA ARMIGERA) IN ORANGES (CITRUS SINENSIS L.) IN THE
EASTERN CAPE PROVINCE OF SOUTH AFRICA is my own work and that all sources
used or quoted have been indicated and acknowledged by means of complete list of references.

11 February 2011

SIGNATURE
(MR K J SIYOKO)

DATE
Dedication

I dedicate this work study to my wife Jacky Siyoko for her inspiration, encouragement and support during the period of my study.
Acknowledgements

I am extremely grateful to my supervisor, Professor David Mxolisi Modise for his tireless guidance and help from the beginning to completion of this study. Prof, without your help, guidance and wisdom, it would have been impossible to complete this study, thank you again.

Many thanks to Mrs. Lebusa Molapo for the support she gave me during the period of my study at the University of South Africa. I am also thankful to citrus farmers in Balfour- Eastern Cape for allowing me to conduct my research experiments on their farms. My appreciation goes to all farm workers for the role they played and the co-operation they showed to ensure that this study is completed with success.

I am grateful to the two professional nurses in Balfour Clinic and Fort Beaufort Hospital for the willingness they showed and support they gave during the interviews. My special recognition is due to my family, Sfiso, Tammy, Abongile and my wife Jacky for being understandable and supportive during my study period.

Now unto Him, that is able to keep me from falling, and to present me faultless before the presence of his glory with exceeding joy, to the only wise God my Saviour be glory and majesty, dominion and power, both now and ever. Amen.
Abstract

The objectives of this study were to establish the effectiveness of chlorpyrifos in suppressing *H. armigera* population in oranges and to determine the effect chlorpyrifos had on the health of farm pesticide operators. Experiments showed that by applying chlorpyrifos on orange trees, *H. armigera* larvae population was suppressed significantly. High fruit yields were realized from trees that were sprayed with chlorpyrifos.

Visual observation of personnel involved in pesticide related duties, revealed that judicious use of pesticides was not practiced by farm workers in all three farms. Data analysis from questionnaires, health records and interviews proved that farm workers suffered from illnesses that were pesticide related. It was mainly those farm workers in the age group of 31 to 35 years who suffered the most from pesticide related illnesses.

Keywords: Effectiveness, Chlorpyrifos, *H. armigera*, Oranges, Yields, Pesticide, Judicious use, Farm workers, Health records, Illnesses.
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<td>AChE</td>
<td>Acetyl cholinesterase</td>
</tr>
<tr>
<td>CGA</td>
<td>Citrus Growers Association</td>
</tr>
<tr>
<td>CLSA</td>
<td>CropLife South Africa</td>
</tr>
<tr>
<td>CPC</td>
<td>Caribbean Plant Commission</td>
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<td>DFPT</td>
<td>The Deciduous Fruit Producers’ Trust</td>
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<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
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<td>European Plant Protection Organisation</td>
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<td>ETI</td>
<td>Ethical Trade Initiative</td>
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<td>GHS</td>
<td>Globally Harmonised System</td>
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OHS - Occupational Health and Safety

OIRSA - Organismo International Regional de Sanidad Agropecuaria

PESTICIDE - means crop protection products

SAHRC - South African Human Rights Council

SANS - South African National Standard

TOTAL SOUTH AFRICA (PTY) LTD - a petrochemical company based in Johannesburg, which markets and sells petroleum products in South Africa, Namibia, Lesotho, Botswana and Swaziland

ULIMOCOR - also known as the Ciskei Agricultural Corporation, was an agricultural parastatal, closed down by the Bisho government in July, 1997
CHAPTER 1
INTRODUCTION AND BACKGROUND

1.1 Citrus production in South Africa

The Citrus Growers Association (CGA) (2006), revealed that citrus (Citrus sinensis) is produced in seven of the nine provinces in South Africa in an area of 57 168 hectares. South Africa produces fourteen different citrus varieties and top of the list are valencia followed by navel oranges and grape fruit. Citrus exports from South Africa to other parts of the world have dramatically increased by 50% over the past nine years as overseas market for fruit had been developed (Bownes, 2003). This author confirmed that this increase in production is attributable to improved agricultural technology, establishment of new orchards and usage of pesticides to control pests.

1.2 Citrus varieties and export in South Africa

The oranges, grapefruit, lemon and lime are the fruits that are mostly exported by South African citrus producers (PPECB, 2009). Records indicated that in 2003 there were 800 000 tonnes of oranges, 160 000 tonnes of grape fruit and 100 000 tonnes of lemon and lime exported to other parts of the world (Department of Agriculture, 2003). Citrus varieties, namely clementine, satsuma and minneola had shown to be the top three highest exported soft citrus at 100 000 tonnes. The major export destinations for South African fruit are Japan, Northern Europe, Southern Europe and the UK. The top three destination ports that receive the South African exported fruit are Rotterdam which
receives 11.5 million cartons; St Petersburg receives 8 million cartons and Sheerness which gets 5.4 million cartons per year. Out of the total fruit produced in South Africa, export constitutes 67%, local 15% and processed fruit 18% (CGA, 2006)

1.3 Pesticide usage in citrus production

Pesticides assist farmers to minimise potential crop yield loss due to pests but they may also pose potential hazard to human health when inappropriately handled. Organophosphate products are most widely used as pesticides today, and are the cause of most incidences of poisoning than any other chemical class of pesticides (http://www.epa.gov/pesticides, 2009). From 1994 to 2000, the South African chemical industry showed 63.5% sales increase of organophosphates products (AVCASA, 1995). Chemical names for organophosphate active ingredients include among others, methyl parathion, ethyl parathion, malathion, diazinon, fenthion, dichlorvos, chlorpyrifos and trichlorforn.

One of the organophosphate product that is commonly used to control insect pests including *H. armigera* on South African citrus farms especially in the Kat river valley in the Eastern Cape midlands is chlorpyrifos. Chlorpyrifos is a nerve toxin and suspected endocrine disruptor with the potential to alter and interfere with the hormonal systems of insects, wildlife and people (http://www.extoxnet.orst.edu./pips/chlorpyr.htm, 2010). This chemical is believed to work by interrupting the electrochemical process that nerves use to communicate with muscles and with one another (Chemical Watch Factsheet, 2000).
1.4 Pesticide management in South Africa

Pesticides in South Africa are regulated according to a government policy which was established by the National Department of Agriculture and Fisheries. The Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies which govern among other things, pesticides and their use was passed by Parliament in 1947 (Government Gazette, 2006). This act is popularly known in the South African chemical industry as Act 36 of 1947. The Government Gazette (2006) expressed concern about the absence of an effective management of pesticides which ensures that pesticides are used in ways that lead to the minimisation of significant adverse effects on human health and the environment. This Government Gazette was aimed at reviewing Act 36 of 1947 in order to address gaps and some concerns which this act overlooked.

1.5 Identified gaps in Act 36 of 1947

Some of the concerns that the Act did not adequately address as mentioned in the Gazette (2006), were:

- The Act does not adequately address Constitutional requirements with regards to Bill of Rights, access to information, transparency in decision making and also just administration
- The Act does not adequately incorporate international obligations and agreements which South Africa is party to
- Anyone who contravenes a provision of the Act or the regulations is guilty of an offence and will be summarily convicted and liable to a fine not exceeding R1000 and such penalties have limited deterrent effect
- There is no requirement for review of registered pesticides
- Lack of pesticide surveillance and monitoring systems to gather information on pesticide usage and their impact on health and environment
- Lack of capacity for research on alternative pest control and crop production measures
- Lack of awareness, education and training appropriate to the public and the user
- Does not encourage registration that favours lower risk products and reduced reliance on pesticides
- The Act does not address the problem of obsolete stockpiles pesticides and their disposal
- The Act does not address the pesticide container management
- Inadequate integration of government departments and complementing legislation
- Lack of protection of vulnerable sub populations

The revision of this policy seeks to ensure that all the existing gaps are closed and that the enforcement of compliance is practised by all who use agricultural chemicals in South Africa.

1.6 **Role played by South African organisations to promote safe use of pesticides**

CropLife South Africa (CLSA) and Agricultural Chemical Distributors Association of South Africa (ACDASA) assist in improving the responsible and safe use of hazardous chemicals (GHS Study, 2003). The responsible use of pesticides includes the implementation of an accreditation system for chemical representatives, the removal of
used chemical containers, the removal and incineration of obsolete chemicals. CLSA had, as part of its Responsible Use programme, promoted responsible use of pesticides to farmers and farm workers. The GHS study (2003) also declared that over the past six years about 600 trainers and 70,000 farmers and users of pesticides had been trained in the safe use of pesticides at an estimated cost of R1.1 million. An Ethical Trade Initiative (ETI) had been established to improve conditions relating to labour standards including health and safety within the wine industry. The ETI included all stakeholders such as producers, Government, labour and non-governmental organisations. The Deciduous Fruit Producers’ Trust (DFPT) provided regular communication to growers of information relating to hazard and maximum residue levels (MRLs) of chemicals industry of agro chemicals.

1.7 Study hypothesis

The hypothesis of this study is summarised by the following statements:

- Chlorpyrifos application on orange trees suppresses *H. armigera* population.
- Improper usage of chlorpyrifos by farm pesticide operators results in human health problems.

1.8 Study objective

The objectives of this study are:

- To establish the effectiveness of chlorpyrifos in suppressing *H. armigera* population.
- To determine the effect of chlorpyrifos on the health of farm pesticide operators.
1.9 Study area

This study took place on three navel orange producing farms which are situated in the Eastern Cape midlands along the Kat river valley near Fort Beaufort. The three farms are among the twenty two farms which were originally owned by white farmers who were forced off their lands through compulsory purchase and the land incorporated in the self governing state of Ciskei. In 1994 these farms were run by Ulimocor, a Ciskeian Agricultural Corporation which appointed black emerging farmers to manage them while the process of changing ownership was taking place (Hassan and Farolfi, 2005).

To date, change of ownership has not yet taken place and these black emerging farmers are engaging the government in order to be issued with title deeds. In a census of agriculture provincial statistics conducted by Statistics South Africa for the Eastern Cape province in 2002, it was revealed that citrus in the Kat river valley is produced in an area of 482 hectares with an output of 10 181 metric tons of oranges.

1.10 Study motivation and rationale

Citrus production requires intensive pest management programmes, which may include multiple pesticide applications each growing season. As a result of dependency on chemical control of pests by South African farmers, pesticide usage for both agricultural and non-agricultural purposes has increased substantially in the past decade and South Africa is the largest market for pesticides in sub-Saharan Africa (London and Baile, 2001). *H. armigera* is among many pests that are imposing a yield loss threat to all citrus producing farmers in the Kat river valley. This pest destroys the foliage of citrus trees and bores a tunnel into citrus fruitlets, and when left untreated can cause yield losses of up to
30% (Mosinke, 2007). For the past five years, all farmers in Kat river valley depended on organophosphates products especially chlorpyrifos to control *H. armigera* population. Due to the length of time that these farmers had been using chlorpyrifos, this pest could have developed resistance and it was therefore necessary to test the effectiveness of chlorpyrifos in controlling the population of *H. armigera*. These farmers make use of farm pesticide operators to apply chlorpyrifos on orange trees in order to suppress *H. armigera* population and thus minimizing its damage on citrus. Whilst recognising the important role of chlorpyrifos to control *H. armigera* in citrus production, it is important to ensure that the safety of pesticide operators is carefully taken care of.

1.1.1 Problem statement

At a wine lands conference held in Cape Town on the 08\textsuperscript{th} October 1999, the Minister of the Department of Labour said “Let us face it, ladies and gentlemen, the reality is that, ‘down on the farm’ (daar op die plaas), all is not well” (Speech by the Minister of Department of Labour, 1999). The minister further added that from January to September 1999, the Department of Labour received 4336 complaints from farm workers on the lack of provision of protective clothing to farm workers and endangering of lives of farm workers through unsafe use of pesticides and herbicides. Excerpts from the *Cape Argus* newspaper (2005) indicated that, 24 farm workers from a wine estate near Worcester in the Western Cape were notified as poisoned with a highly toxic aldicarb contained in wine they drank. The wine had been decanted from a 50 litre barrel which had been used to store the wine used for distribution to the workers. The newspaper further reported that a one-year-old baby boy was rushed to hospital with organo-phosphate poisoning.
Indeed pesticide exposure due to usage by untrained personnel is a significant hazard for South African farm workers particularly in the fruit industry, with South Africa representing the largest market in sub-Saharan Africa. According to London and Baile (2001), although cases of acute poisoning notified to authorities nationally rarely exceed 200, there is considerable underreporting of such cases. The World Health Organization (1990) estimated an annual worldwide total of some 3 million cases of acute, severe poisonings including suicides matched possibly by a greater number of unreported, mild-to-moderate intoxications, with some 220 000 deaths. Despite the lack of data, it is evident that it is particularly those without access to knowledge who bear the brunt of acute and chronic morbidity due to pesticide exposure. London and Baile (2001) supported the notion that pesticide poisoning is a major public health problem in developing countries particularly in settings of low education and poor regulatory frameworks.

*Helicoverpa armigera* is one of the key pests causing yield losses, infesting crops such as cereals, pulses, cotton and fruit crops as well as wild hosts (Gupta *et al.* 2003). Overall, the *H. armigera* affects economies by reducing yields, lowering crop values and causing market loss due to quarantine restrictions (Fowler and Lakin, 2001). Mosinkie (2007) reported that *H. armigera* is estimated to cause yield losses of 15 to 30% on cotton. This pest is listed by the European and Mediterranean Plant Protection Act as an A2 quarantine pest and is also considered a quarantine pest by the Caribbean Plant Commission (CPC), Organismo Internacional Regional de Sanidad Agropecuaria (OIRSA), and the country of Brazil (EPPO, 2000). Ecological and physiological features like high fecundity, multi-voltinism, ability to migrate long distances and diapause during unfavourable conditions, contribute for its severity in different situations (Gupta *et al.*
2003). There seems to be little available information even on the effectiveness of chlorpyrifos in controlling pests in citrus under South African conditions.

1.12 Structure of the study

This study is made up of five chapters. Chapter 1 gives an introduction, background and pesticide usage in South African citrus production. This chapter also gives details of the aims, rationale and objectives of this study. Chapter 2 displays literature review and in depth discussions which relate to chlorpyrifos usage in orange production, *H. armigera* destructive activities on crops and pesticide operators’ risks in handling pesticides. Chapter 3 discusses general materials and methods which were used to collect information for this study. This chapter has been divided into part A which focuses on experiments conducted on the three farms and part B which discusses the questionnaire method of collecting respondents’ data. Chapter 4 presents and discusses the statistical analysis results of all data collected during the course of this research. Chapter 5 gives summary and conclusions which have been drawn from the results of experiments and data analysis performed for this study. This chapter also mentions recommendations and suggested further research studies based on findings from this study.
2.1 Citrus origin and its production

Citrus (*Citrus sinensis L.*) is a very ancient crop known to have been in existence over 4000 years ago (Mukhopadhyay, 2004). Whiteside *et al.* (1998) revealed that all citrus fruits originated and are native to south eastern Asia. According to Mitra (1997), oranges are grown in tropical, subtropical and temperate regions that have a suitable climate and such regions are within the latitude of 41°N and 34°S. Rieger (2006), indicated that in 2004 sweet orange production was at 63,039,736 MT or 139 billion pounds. Brazil is now the largest producer of citrus world-wide and its industry is orientated towards production of oranges for processing.

The United States of America, China and Spain, are other largest citrus producing countries followed by Mexico, Italy, Japan, Egypt, Argentina, Turkey, Israel and Morocco (PPECB, 2009). Although South Africa is one of the smaller producers by world standards, it sets the example on the production, development and export of citrus fruit and products amongst the southern hemisphere countries which include the continents of Australia and South America ([www.fao.org/unfao/bodies/ccp/citrus/98/98-5e.htm](http://www.fao.org/unfao/bodies/ccp/citrus/98/98-5e.htm). 2010). Citrus production in South Africa has been indepthly discussed in the preceding chapter.
2.2 Taxonomy of *citrus* (*Citrus* spp.)

The genus *Citrus* belongs to the Rutaceae or Rue family, subfamily Aurantoideae (Rieger, 2006). This author also mentioned that the Rue family has 150 genera and 1600 species worldwide. Ray and Walheim (1980) and Rice *et al.* (1992) described citrus as a deciduous to evergreen tree or shrub with sharp spines; leaves are unifoliate, alternate, coriaceous or curtaceous and punctuate with aromatic pellucid glands; flowers are solitary, in cymes or racemes, small or large, bisexual or staminate and sweet scented. These authors further asserted that flowers are cross pollinated and fruits are segmented hesperidium containing seeds near the ventral side and stalked, fusiform; pulp vesicles contain sweet or sour juice. The rind consists of an outer coloured portion called flavedo and an inner white spongy portion called albedo. The flavedo contains many oil glands and it turns yellow or orange or red at full maturity (Ortuño *et al.* 2005). There may be no seed or there may be many seeds attached to the outer wall of each segment. The seeds contain one or more white or green embryos that are produced asexually by mitotic division of the nucellus.

2.3 *Citrus sinensis*

*Citrus sinensis* is a binomial name for sweet oranges (Oliveira *et al.* 2005). Sweet oranges are categorised into four groups namely; common oranges, blood oranges, navel oranges and acid less oranges (Jackson, 1999). Valencia, torocco, navel and succari are examples of common, blood, navel and acid less oranges respectively (Nunes, 2008). Yadav (2007) ranked sweet oranges as second important crop in citrus. Out of the four groups of sweet oranges, navel is the most commonly planted type of orange in the Eastern Cape midlands (Statistics South Africa, 2002).
2.4 Navel oranges

Navel oranges develop from a secondary ovary embedded within the usual ovary and as the second ovary enlarges, it also causes the navel orange to enlarge (Ray and Walheim, 1980). Navels are generally seedless and make excellent quality fresh fruits with a crisp, rich flavour and ease of peeling and separation. They are among the finest table fruits, and certainly the standard of excellence among sweet oranges.

2.5 The importance of navel oranges

The sweet orange (Citrus sinensis) is one of the world’s most important fruit crop which is consumed mostly as fresh produce or juice (Liu and Deng, 2007). From ancient time, its nutritional significance was well known particularly as the principal source of vitamin C and folic acid (Oben et al. 2009). Fresh oranges are rich in vitamin C which plays a vital role in prevention of scurvy and other human related illnesses. Mitra (1997) also confirmed the nutritive significance of oranges by stating that orange flavonoids namely; naringin, rhoifolin, lomcerin, hesperidin, neohesperidin, citronin and tangeretin are located in the rind and juice segments of an orange.

Mukhopadhyay (2004) indicated that the flavonoids have the ability to prevent invasion of normal tissues by cancer cells and added that orange hesperidin, naringin, tangeretin and nobiletin have anti-inflammatory and anti-allergic properties and these flavonoids also improve circulatory system. This author declared that oranges’ therapeutic and nutritive values along with its taste and flavour have placed it in the regular dietary list of the people living in advanced countries.
2.6 Citrus pests

Rice et al. (1990), stipulated that, a number of insects attack citrus but the severity of damage varies with location and predator population. Peña, et al. (2002) listed about 875 insects and mites, albeit less than 10 % are of major concern. These authors listed the most serious pests for citrus as scales (soft brown, green and wax scales), mealybugs, fruit flies (Mediterranean and Natal fruit flies), thrips, mites (citrus red mites), aphids (black and brown aphids), citrus leafminer, false codling moth and citrus psyllid.

*Helicoverpa armigera* is among lepidopterous pests which are classified as fruit borers (Moore et al. (2004). This pest is among the many pests that are problematic in the Eastern Cape midlands and if not controlled can cause huge decline in orange yields.

2.7 The *Helicoverpa armigera*

*Helicoverpa armigera* is present in most of mainland Europe, Asia, Africa and Australasia (Venette et al. 2003). This notorious and well known pest is extremely polyphagous and is a major pest in Southern Hemisphere (Prinsloo, 1984). Moore et al. (2004) declared *H. armigera* as the pest which ranks as the most important lepidopteran pest in South Africa. European Plant Protection Organisation (EPPO) (1981) classified this pest as belonging to animal kingdom in class insecta in the order of lepidoptera and has common names such as Hübner, Heliothis, Old World (African) bollworm and New World or American bollworm. In South Africa, *H. armigera* is known as the American bollworm (Pena et al. 2002). Its life cycle consists of four stages namely eggs, larvae, pupa and adult. Caterpillars pass through four developmental instars and ultimately reach 30 to 40 mm in
length and have stripes and short black hairs along the length of the body (http://www.defra.gov.uk/planth/pestnote/helicov.htm, 2010).

Under South African weather conditions, *H. armigera* oviposition period is 10 to 23 days, with an average of 730 eggs per female (Cabi, 1996). Hairy surfaces are preferred for oviposition which is closely linked with the period of bud burst and flower production in most host plants. Eggs hatch in three days at 22.5°C and nine days at 17.0°C and the larval period lasts 18 days at 22.5°C and 51 days at 17.5°C. The Data Sheets of the EPPO (1981) on Quarantine Pests asserted that the rate of development of the larva is also affected by food availability and fully grown larvae leave the plant to pupate in the soil at a depth of 3 to 15 cm. In Southern Africa, the minimum pupal period in summer is 12 days, increasing as the temperature fall to about 57 days. Emerging female moths must feed before their ovarioles are mature. The average life span for females and males in South Africa is 9 and 14 days respectively.

### 2.8 *Helicoverpa armigera* damage and its economic impact on crop production

The infestations of this pest occur regularly throughout the growing season. The insect pest outbreaks occur during the active growth of host plants, mainly from spring through to summer into autumn. Gerber (2007) confirmed that the peak infestations of *H. armigera* in South Africa takes place during the months of September to November with a second peak in February and March depending on weather conditions. This pest is ubiquitous throughout South Africa, affecting a range of crops. Its larvae may cause damage to citrus blossoms, fruitlets, and young growing tips even on fruit buds. Aslam *et al.* (2004) indicated that *H. armigera* destructive activities on fruiting parts of the crop result in 20% to 60% decrease in market value of the crop. Citrus trees are one of the
most vulnerable hosts that are attacked by *H. armigera*. The direct damage to flowers and fruiting structures by larvae cause great losses in most crops. Damage appears as tiny holes in flower buds or petals, leaves and fruit. According to Kaiser and Sheard (2001), the best known damage is on growing tips of the young trees where bollworms make holes into the tips and tunnel through the tightly folded young leaves, where they may be found. Venette et al. (2003) supported this statement and further stipulated that damage caused by the larvae can result in secondary problems such as rotting and ultimately complete plant loss. These authors go on to say that huge loss of agricultural crops can result if infestations get out of hand in crop production.

EPPO (1981) stipulated that an outbreak of *H. armigera* occurred on young *Pinus radiata* in New Zealand in 1969 to 1970 when the larvae consumed more than 50% foliage of about 60% trees. Braun (1997) also agreed that this pest can cause 20 to 50% yield loss in cotton. In 2007, Mosinkie declared that *H. armigera* is estimated to cause yield losses of 15 to 30% on citrus. Sharma (2001) was in accord with this notion and confirmed that this pest caused an estimated loss of over US$2 billion annually in the semi arid tropics despite US$500 million worth of pesticides applied for controlling this pest. Koul et al. (2004) also reported that in China, *Bacillus thuringiensis* cotton was approved for commercial release in 1997 due to a sharp reduction in cotton production caused by losses and control associated with cotton bollworm, *H. armigera*. To mitigate the risk of yield losses due to *H. armigera* activities, South African farmers especially farmers in the Kat river valley of the Eastern Cape midlands spray chlorpyrifos pesticide onto orange trees to suppress its population.
2.9 *Helicoverpa armigera* resistance to pesticides

Horne and Page (2008) testified that *H. armigera* in the Australian agriculture was found to be resistant to many pesticides. These authors assigned the resistance to regular use of broad spectrum pesticides. Sharma (2001), as cited by Koul *et al.* (2004), reported that resistance to pyrethroid insecticide caused *H. armigera* to become one of the economically damaging pests in Indian agriculture. Moore *et al.* (2004) also revealed that, poor results were obtained from parathion application at Paksaam farm which is situated in the Gamtoos river valley in the Eastern Cape Province where citrus oranges were sprayed with parathion to control *H. armigera* population. The poor results obtained from such experiment were assigned on the lateness of parathion application.

2.10 Facts about chlorpyrifos

EPA (2002) described chlorpyrifos as an organophosphate insecticide, acaricide, and miticide used to control foliage and soil borne insect pests on a variety of food and feed crops. Cremlyn (1991) agreed that chlorpyrifos is a very valuable contact insecticide with a wide spectrum of activity such as by contact, ingestion and vapour action. It is an organo-phosphorous insecticide and its chemical name is 0, 0-diethyl 0-(3, 5, 6-trichloro-2pyridyl) phosphorothioate (Watterson, 1998). The chemical formula for chlorpyrifos is C$_9$H$_{11}$Cl$_3$NO$_3$PS and its synonym name is chlorpyrifos-ethyl (Plate 2.1). It has an oral rat LD$_{50}$ which ranges from 95 to 270 mg/kg (Kidd and James, 1991). Chlorpyrifos is registered for the control of cutworms, cockroaches, grubs, flea beetles, flies, termites, fire ants, mosquitoes and lice. It is used as an insecticide on grain, cotton, fruit, nut and vegetable crops as well as on lawns and ornamental plants.
2.10.1 Chlorpyrifos mode of action

Organophosphates poison insects and mammals primarily by phosphorylation of the acetyl cholinesterase enzyme (AChE) at nerve endings (Gomes et al. 1997). The result is loss of available AChE so that the effector organ becomes over stimulated by the excess acetylcholine in the nerve ending (Moretto and Lotti, 1997). The enzyme is critical to normal control of nerve impulse transmission from nerve fibres to smooth and skeletal muscle cells and autonomic ganglia, as well as in the central nervous system (Gallo and Lawryk, 1991). Some critical proportion of the tissue enzyme mass must be inactivated by phosphorylation before symptoms and signs of poisoning become evident (EPA, 2002).

2.10.2 Chlorpyrifos trade names in South Africa and other countries

Gerber (2007), listed chlorpyrifos trade names as Efekto Chlorpyrifos, Grovida Chlorpyrifos (480g/l EC), Dursban 2E (240g/l EC), Lorsban (150g/l GR), Ant Dust (30g/kg DP), Dursban 75 (750g/kg WG) and Everdeath (20 g/kg chlorpyrifos/50 g/kg
carbaryl). This pesticide is known in other countries by different names such as Dursban, Lorsban, Dursban 4E, Brodan, Detmol UA, Dowco 179, Empire, Eradex, Paqeant, Piridane, Scout and Stipend (http://extoxnet.orst.edu/pips/chlorpyr.htm, 2010).

2.10.3 Dangers of chlorpyrifos in human health

Marais (2004) claimed that the most widely recognised hazards of farm workers are pesticides and agricultural machinery, but agricultural workers are also exposed to severe climatic conditions. Chlorpyrifos is among many other pesticides that are used for pest control by farmers in the Kat river valley of the Eastern Cape Midlands. According to Whitney et al. (1995), chlorpyrifos may enter the human body through inhalation, skin absorption or ingestion. It is moderately persistent and retains its activity in soil for 2 to 4 months (Cremlyn, 1991).

Chlorpyrifos can cause cholinesterase inhibition in humans and that is, it can overestimate the nervous system causing nausea, dizziness, confusion, and at very high exposures will cause respiratory paralysis and death (Cataño et al. 2000). Acute poisoning symptoms such as persistent cough, back ache, nausea, short breath, dizziness, blurred vision and sweating develop during exposure or within twelve hours of contact with chlorpyrifos (Ecobichon, 2001). Severe poisoning is indicated by incontinence, unconsciousness and convulsions, slow heartbeat, salivation and tearing are also common (Pesticide Fact Sheet, 1984). Watterson (1998) also indicated that chlorpyrifos has chronic carcinogenicity, mutagenicity and reproductive effects to human health. Its poisoning causes sleep pattern and behavioural changes lasting over a year following exposure to organophosphate insecticides (www.beyondpesticides.org, 2009). Rother et al. (2008) suggested that spray operators must exercise extra caution
when working or applying chlorpyrifos by wearing protective clothing and avoid contact with it via accidental spillage or spray drift.

2.11 Chlorpyrifos residue on citrus fruit

In a series of supervised trials in South Africa from 1975 to 1976, Hollick and Sandenskog (1976) reported that the pulp and peel of oranges were analysed separately to determine chlorpyrifos residue on fruit. This report revealed that chlorpyrifos residues were not detected in any of the pulp samples including those from fruit treated at exaggerated rates. The report also stated that residues in the whole fruit ranged from 0.3 to 0.72 mg/kg.

2.12 Chlorpyrifos usage in the Eastern Cape midlands

In the Eastern Cape midlands, chlorpyrifos is used to control a wide variety of pests including *H. armigera*. On these farms, chlorpyrifos is applied during November month as a full cover spray when orange trees are at blossom stage or when the pest is noticed (http://www.efekto.co.za/products_profile, 2009). The results of a research conducted in Tierhok farm in May 2006, showed that the use of chlorpyrifos on navel oranges to suppress *H. armigera* population resulted in an increase of 160 yield index as compared to 80 yield index of untreated orchards (Moore, 2007). This research also revealed a 2% *H. armigera* fruit damage of the chlorpyrifos treated orchards and 15% fruit damage for untreated orchards.

Farm workers had been identified as a high risk group for occupational poisoning (Gomes *et al.* 1997). Brenan (2002) emphasized that pesticide education and training are critical to reducing personal and environmental exposure to pesticides. Safety
considerations pertaining to pesticide usage include education and training programmes that relay how the chemicals can be used safely and efficiently in order to alleviate pesticide poisoning to farm pesticide operators. Subsection 5.2.1.5 of the South African National Standard (SANS) 10206 (2005), stated that all pesticide operators should receive practical training and shall not be allowed to handle pesticides unless they know the risks involved and the precautions to be taken.

2.13 Pesticide operators and pesticide usage

Most of the South African workers are employed in the agriculture sector and are exposed to large quantities of agricultural chemicals, especially pesticide (London and Rother, 2000). Gomes et al. (1997) affirmed that farm workers have been identified as a high risk group for occupational poisoning. This notion is supported by a report of an inquiry that was released in 2002 by the South African Human Rights Commission (SAHRC), which highlighted the appalling conditions faced by South African farm workers. Citrus farmers in the Kat river valley often utilize their farm pesticide operators to assist with chlorpyrifos and other pesticide applications activities. These workers are exposed to pesticides which can lead to poisoning especially if judicious use of these chemicals is not practiced.

Matthews (2006) remarked that, exposure to pesticides tends to be greatest for those who mix and apply the sprays in the field, especially those employed by contractors or who work on the large estates and plantations where pesticides may be applied on consecutive days and sometimes for a long period during the year. Pesticide workers are at increased risk for pesticide related illnesses because they are more likely than other workers to be exposed to pesticides. Rother et al. (2008) claimed that there is not
adequate support for emerging farmers to manage pesticides safely and this lack of support puts their families, workers and surrounding communities at increased risk of short term and long term health problems. According to Bradman et al. (2009) family members of pesticide operators also stand a risk of poisoning by the “take home” pesticide residues which are transported on pesticide operators’ skin or clothing. Mekonnen and Agonafir (2002) confirmed that the health hazards associated with pesticide handling are little understood by pesticide workers. Since the effects of these chemicals on the health of workers and their families including chronic effects are largely unknown only severe or fatal poisonings are reported (Rother et al. 2008).

Pretty (2005) affirmed that farmers generally do know the dangers of pesticides, but this knowledge alone is not sufficient to change their behaviour. This author testified that the first priority is usually economic survival, which generally overrides concerns for health. Bull (1985) attributed much of pesticide misuse by farm pesticide operators to illiteracy, lack of training and equipment, lack of support by farm owners and managers and lack of effective legislation controls. The result of all these factors is the regular and widespread incidence of poisoning. It is challenging for farmers to provide adequate training to farm pesticide operators in South Africa due to language barriers and differences in learning styles.

Training may not be appropriate because of the low educational level of most farm workers. Training of pesticide operators in the judicious use of chlorpyrifos becomes indispensable in order to ensure that human poisoning is curbed. London (2003) agreed with the notion that pesticide poisoning is a major public health problem in developing countries particularly in the settings of low education and poor regulatory frame work. The lack of monitoring is of concern given the significant opportunities for human exposure
and the increasing number of chronic health conditions being associated with long term exposures to pesticides. Pesticide operators who mechanically apply chlorpyrifos should be aware of its dangers on their health and practice judicious use whenever pesticides are handled.

2.14 **Promotion of judicious use of pesticides in the Western and Eastern Cape Provinces**

In 2003, Total South Africa, a petrochemical company based in Rosebank in Johannesburg entered into a contract with the Association of Veterinary and Crop Associations of South Africa (AVCASA) to promote safe use of pesticides by training farm managers, farm supervisors, government extension officers, industrial personnel, farm pesticide operators and farm general workers. According to AVCASA (2007), this company had trained more than 3500 trainees in the responsible use of pesticides in the Eastern and Western Cape Provinces collectively. Since 2003 to early 2007, there were 535 one-day training sessions that had been conducted and presented to farm pesticide operators in both provinces. Within the same period, there were 26 two-day training programmes that had been conducted and presented to farm managers, extension officers, industrial personnel and pesticide marketing agents.

The two types of training programmes entailed six modules namely; understanding pesticides, personal health and safety, safety in transporting pesticides, safe storage of pesticides, management of pesticide storeroom, disposal of empty pesticide containers and South African legislation pertaining to pesticides usage. One-day training programmes for farm pesticide operators were conducted on various farms while the two-day training programmes were conducted in various venues such as, on farm, in offices
and in industrial plants. Interactive and hands-on learning activities were used to facilitate effective learning. Because of the intensive nature of the training with a high trainer to trainee ratio, the programme was limited to a class of twelve to twenty trainees at a time. A pre self-assessment of trainee level of knowledge is conducted before the beginning of each training session.
CHAPTER 3

PART A - GENERAL MATERIALS AND METHODS

Experiments on the impact of chlorpyrifos on the larvae of *H. armigera* on oranges

3.1 Introduction

The research experiments described in this chapter took place on three different citrus farms which are situated along the upper Kat river valley in the Stockenstroom area near Fort Beaufort in the Province of the Eastern Cape (Plates 3.1, 3.2 and 3.3). This chapter also discusses methods and materials used to gather data for this study.

3.2 Orchard selection

One orchard was selected from each farm for the purpose of carrying out research experiments. Orchards M38, KA, and T9 (Plates 3.1, 3.2 and 3.3) with extents approximately two hectares each, were selected from farm A, B and C respectively. Orchard KA and T9 were both planted in 1985 and M38 of farm A was planted in 1987. These orchards were situated closer to the Kat river bank and had an oakleaf soil type (although there were no soil maps available). All three farms were in the same vicinity within a radius of 5 km and the orange trees consisted of palmer navel scions grafted in rough lemon rootstocks. The selected orchards were surrounded by silver oak windbreakers. The first and the second rows of orange trees on the periphery of the orchards were regarded as guard rows and therefore not utilized for data collection. Fortunately, farm C’s orchard T9 was not utilizing chemicals for control of pests and this
presented an opportunity to use it as a control. Ideally orchards should have had all treatments imposed but due to farmers’ plans and programmes that could not be possible.

Plate 3.1. Orchard M38 on farm A

Plate 3.2. Orchard KA on farm B
Plate 3.3. Orchard T9 on farm C

3.3 Sampling and tagging of orange trees

Fifteen trees from each farm were randomly selected and tagged for experiment and identification purposes. White plastic name tags were affixed on the selected trees by means of pieces of wire (http://www.proaxis.com/johnbell/equipment/equip56a.htm, 2010). The pieces of wire and plastic name tags had been chosen in order to withstand the pressure of the spray mixture from the spray machine, the different weather conditions and to avoid any possibility of the ink of name tags reacting with the pesticide mixture. The trees were identified using the first letter of the farm and the number of the tree being tagged.
3.4 **Scouting for *Helicoverpa armigera* larvae**

Scouting took place in November 2008 when all citrus trees were starting to drop flower petals and fruitlets were formed on trees (Kaiser and Sheard, 2001). Scouts commenced with scouting at ten o’clock in the morning and ended at four o’clock in the afternoon. Scouting was conducted by three scouts on all randomly selected tagged trees. The method and procedure used for scouting was adopted from Jackson and Davies (1999), where scouts’ eyes follow an imaginary straight line from the top of the tree canopy to its base. In this way of scouting, scouts are not allowed to look sideways while scouting. There were ten imaginary straight lines per each tree which the scouts had to follow in their scouting operation. The first round of scouting took place in the third week of November 2008 in all three farms and it was conducted before orange trees were
sprayed with chlorpyrifos spray mixture. The second round of scouting took place in the fourth week of November 2008 in all three farms after farms A and B were sprayed with chlorpyrifos mixture. Farm C was never sprayed because its orchard was used as a control. Each larva that was found got recorded against the tree name and the imaginary line on which it was found. The scouting records of *H. armigera* larvae before spraying with chlorpyrifos spray mixture are depicted in the accompanying graph (Figure 3.1).

![Figure 3.1 Number of larvae per farm before spraying trees with chlorpyrifos pesticide](image)

Figure 3.1 Number of larvae per farm before spraying trees with chlorpyrifos pesticide
3.5 *Helicoverpa armigera* damage to leaves and orange fruitlets

The damage to the leaves and the fruitlets by *H. armigera* larvae was identified during the scouting process. Damage was evident on leaves and some fruitlets were either partially or completely damaged (Plate 3.5). Some fruitlets survived the activities of the larvae while others died and fell off the trees (Plate 3.6).

Plate 3.5. *H. armigera* damage on orange fruitlets and leaves
Plate 3.6. Borehole and a bruise caused by *H. armigera* on orange fruitlets

### 3.6 Spray equipments

The equipments and machinery listed below were used to perform pesticide application experiments in the three selected orchards:

- A 60 killowatt tractor
- A 2500 litre capacity tractor drawn high pressure tank with 30 cone nozzles
- A two litre measuring jar
- A 20 litre container of chlorpyrifos concentrate
- A five litre container for pesticide mixing
- Clean river water
- One metre long stirrer
3.7 Mixing of chlorpyrifos

The pesticide label stipulated an application rate of 75 ml of chlorpyrifos concentrate per 100 litres of water for the purpose of controlling *H. armigera* larvae on citrus. Two litres of chlorpyrifos concentrate were measured into a two litre jug and poured into a five litre container (Plate 3.7). The chlorpyrifos in the five litre container was mixed with three litres of clean river water for easy pouring into the tractor drawn high pressure tank. The content of the five litre container was poured into a half empty tractor drawn spray tank. The agitator inside the tank was rotating in order to ensure homogeneous mixing of chlorpyrifos concentrate with water.

Plate 3.7. Chlorpyrifos measured in a two litre jug
3.8 Pesticide spillage during pesticide mixing

Plate 3.8, shows a pesticide spillage which took place during the preparation of chlorpyrifos spray mixture. This spillage was left unattended for the soil to absorb. Equipment for cleaning up of pesticide spillage such as pesticide spill kit was unavailable during the mixing of the pesticide.

Plate 3.8. Pesticide spillage during measurement of chlorpyrifos concentrate
3.9 Method of orchard spraying

Ideally each orchard would have had all treatments including the control, but this was not the case because orchard management would not be possible where certain portion was sprayed with the pesticide and another without. The researcher was conscious of this dilemma but had to operate under existing farm management programmes. Comparison of results from these three farms should be considered against a backdrop that there could be an influence due to the micro climate in the individual farms. This matter is explained further in section 5.2.

The method of tank calibration was adopted from Hawker and Keenlyside (1993). The chlorpyrifos spray mixture was applied to orange trees using a tractor drawn high pressure tank with a capacity of 2500 litres (Plate 3.9). The delivery rate of the spray mixture per cone nozzle was found to be 5 litres per thirty seconds at an engine speed of 25 revolutions per minute. The tank operated at a pressure of 15 Kilopascals and the tractor was engaged in the third low gear. The average day temperature was 18.5 °C and a North Westerly wind speed of 10 km/h was measured using an anemometer. The spray mixture was sprayed through nozzles with a front diameter of 3.5 cm and a back diameter of 5 cm. The vertical distance from one nozzle to the other was 18 cm. One full tank of chlorpyrifos spray mixture enabled the pesticide operator to apply one full cover spray per orchard.
Plate 3.9. Chlorpyrifos mixture sprayed on oranges trees at farm B

3.10 Inspection of mature oranges for *H. armigera* damage

Harvesting of mature oranges from the three farms took place in July 2009. Orange harvest bags were used to collect oranges from trees and were emptied into a harvest bin. The average capacity of an orange harvest bag ranged from 26 to 46 oranges depending on the fruit size. One orange bin was used to harvest oranges into, and the second was used for collection of oranges which sustained bruises from *H. armigera* larvae activities.
CHAPTER 3 (continued)
PART B – GENERAL MATERIALS AND METHODS
Questionnaire survey on the health status of farm workers

3.11 Introduction

Information pertaining to the effect of pesticides on the health of farm workers was collected using three methods namely questionnaires, interviews and perusal of farm workers’ health records.

3.12 Request to access private information

An application request for approval to undertake a research project involving humans was submitted to the Research and Higher Degrees Committee of the College of Agriculture and Environmental Sciences for consideration and approval was granted. Permission was also granted by the Balfour Clinic and Fort Beaufort Hospital to conduct interviews with one health professional from each institution.

3.13 Consent forms

Consent forms were explained to farm owners and respondents before interviews took place. The signing of the consent forms by all respondents took place in the presence of farm owners. Respondents were made aware that by signing the consent forms they agreed to declare their health status and permission had been given to the researcher to peruse their health records for the purposes of this study. Farm workers willingly signed
the consent forms and knowingly granted permission for their health records to be examined by the researcher. A copy of a consent form has been attached herein as Appendix A.

3.14 Sample size

The average number of farm workers on each farm was 10 thus the sample size was governed by these numbers. The respondents for this study consisted of ten farm workers from each farm which made a group of thirty respondents. This group was divided into four age groups namely; 20 to 25, 26 to 30, 31 to 35 and 36 years and more. Age group 20 to 25 consisted of six respondents. There were nine respondents for age groups 26 to 30 and 31 to 35 years respectively. The age group 36 years and up had six respondents. All respondents were males and no females were included in this study because females only worked on these farms as casual workers during the orange picking season.

3.15 Questionnaires

Thirty structured questionnaires were used for the collection of information from a total of thirty farm workers. The questionnaires were structured to address six subjects namely; access to pesticides, performance of pesticide related duties by farm workers, farm workers’ pesticide safety knowledge, health of farm workers, pesticide container management and farm workers’ rights. The questions and style of questionnaires were adopted from Gafni et al. (2002). Questionnaires comprised of sixty eight questions. Thirty seven of these questions were open ended and the remaining 31 were closed questions. The majority of the questions were made open ended in order to provide
ideas, details and to pinpoint problems. A copy of the questionnaire is attached to this study as Appendix B.

3.16 Testing of questionnaires

The questionnaires were tested according to Norland (1990), in order to establish reliability. This author further explained that questionnaire reliability is established using a pilot test by collecting data from 20 to 30 subjects not included in the sample. In June 2008, questionnaires were tested and completed by engaging twenty respondents from three neighbouring farms. Initially, the questionnaires comprised of one hundred and five questions and it took an average of seventy two minutes to complete one questionnaire. After the testing, the questionnaires were re-organised and re-worded for easy understanding by respondents and this change resulted in the reduction of questions to sixty eight. Editing open ended responses requires collapsing the many responses into some reasonable number (Esposito, 2002). A cell phone stopwatch was used to measure the time taken to complete each questionnaire. After revision of questionnaire content, each questionnaire took up to a maximum of forty five minutes to complete.

3.17 Completion of questionnaires by respondents

In July 2009, all questionnaires were completed by thirty respondents. Seventeen out of thirty respondents were illiterate and the researcher gave assistance by recording the respondents’ answers in the questionnaires. Each questionnaire interview took place in the orchard on a one on one basis (Plate 3.10).
Plate 3.10. Farm worker interviewed for the completion of a questionnaire

3.18 Interviews with health professionals

Two health professionals were interviewed at Balfour Clinic and Fort Beaufort Hospital respectively around the same period of orange harvesting on these farms. A list of guiding questions was compiled and used to probe information pertaining to pesticide related poisoning incidences which were treated at these public health facilities. The list of questions asked from health professionals have been attached to this study as Appendix C.
3.19  **Farm workers’ health records**

Health records for the thirty farm workers were scrutinized to establish pesticide poisoning related illnesses.

3.20  **Coding of questionnaires for statistical analysis**

The respondents’ information gathered from the questionnaires was coded for easy interpretation of respondents' responses and for analysis using GenStat – Release 7.22 DE (2004).
4. **Introduction**

This chapter discusses results obtained from experiments conducted on the three farms and also gives a statistical analysis of questionnaire data using GenStat – Release 7.22 DE (2004). Data was subject to analysis of variance (anova) and means separated using the standard error difference (sed) at p<0.05.

4.1 **Effect of chlorpyrifos on *H. armigera* population**

The effect of chlorpyrifos on suppression of *H. armigera* population was experimented on all three farms and the results obtained are discussed in the following sections.

4.1.1 **Scouting results**

The graph below (Figure 4.1) displays the scouting results for *H. armigera* larvae per farm before and after spraying with chlorpyrifos mixture. Farm A before sprayed with pesticide showed the highest larvae population of 52 and farm B had the lowest larvae population of 18. The high number of larvae at farm A is attributable to the micro climate of this farm especially high temperature which prevailed in the valley in which the orchard is located (information obtained by verbal discussion with the citrus farmer, 2009). Gupta *et al.* (2003) agreed that high temperatures favour quick development of *H. armigera* larvae.
and on the contrary, low temperatures delay larvae development. Farms A and B after being sprayed with chlorpyrifos showed a larvae population decline of 95 % and 100 % respectively. Farm C was used as a control and after three days of not spraying with chlorpyrifos it showed larvae population increase of 220 %. This increase in larvae population at farm C could be due to factors such as warm weather, availability of feed to *H. armigera* larvae and to non spraying treatment. This result suggested chlorpyrifos was effective in suppressing *H. armigera* population on orange trees in that; all trees sprayed with chlorpyrifos showed a decline in *H. armigera* larvae population and trees not sprayed showed a three-fold increase in the population of this pest.

![Figure 4.1. *H. armigera* larvae numbers before and after spraying with chlorpyrifos](image)

**Figure 4.1.** *H. armigera* larvae numbers before and after spraying with chlorpyrifos
4.2 Effect of *H. armigera* population on oranges

The oranges harvested from the tagged trees were counted and inspected for *H. armigera* damages. The results found are discussed in the following sections.

4.2.1 Harvested orange bags

Figure 4.2 shows a significant difference at \( p < 0.001 \) in the number of fruits between the three farms. Farm A and B had significantly at \( p < 0.001 \) higher numbers of matured fruits than farm C. In view of the fact that farms A and B were sprayed with chlorpyrifos, *H. armigera* destructive activities were curbed saving oranges from being destroyed by this pest. The suppression of the pest population in these two farms resulted in fewer destroyed oranges per tree and thus better orange yields were realized as compared to farm C.

On the contrary, farm C, where chlorpyrifos was not sprayed, it was found that there were more oranges that were destroyed due to the destructive activities of *H. armigera* larvae and less orange yield was realized from this farm compared to farms A and B. This result provided evidence that when there was no control of *H. armigera*, there would be many destroyed oranges which would result in reduced yield of oranges. Likewise, where there was control of *H. armigera* pest using chlorpyrifos, less destroyed oranges would be anticipated which would result in higher yield of oranges compared to untreated trees. A similar result was obtained using navel oranges in an orchard in South Africa on Tierhok farm where oranges trees sprayed with chlorpyrifos showed an increase in orange yield (Moore, 2007).
Figure 4.2. Matured orange fruits harvested at farms A, B and C.

4.2.2 Damaged mature fruits

The total harvested oranges from the tagged trees in farms A, B and C tallied 3409, 2847, and 1290 respectively. *H. armigera* damaged oranges from farms A, B and C were found to be 41, 21 and 315 respectively. Farm C showed a significant p< 0.001 difference in the number of damaged oranges. The highest number of damaged fruits was evident at farm C where trees were not sprayed with chlorpyrifos to control *H. armigera*. Farm B exhibited the lowest number of damaged oranges, followed by farm A (Figure 4.3). The results in figure 4.3 were expected and confirmed that where *H. armigera* pest is not controlled, there is likelihood for damage and destruction of oranges. Damaged fruits have a negative economical impact to the overall financial performance of the farm in that; fruits
destined for overseas markets are sold locally or are used to make orange juice for the local market.

![Graph showing the number of damaged fruits in farm A, B, and C](image)

**Figure 4.3.** Number of damaged fruits in farm A, B and C (error bars inserted)

### 4.2.3 *H. armigera* damage on matured orange fruits

On fully grown oranges, the bruises caused by *H. armigera* grew to become sunken damages on the skin of the orange fruit with varying sizes and shapes as depicted in Plate 4.1. These fruits sustained bruises on the flavedo and the damage did not penetrate the albedo of the orange fruit.
Plate 4.1. Matured oranges showing various damage patterns caused by *H. armigera* larvae

4.3 Questionnaire data analysis

The statistical analysis of the questionnaire data was interesting and exciting because it brought a revelation of information that was not anticipated and which was new to the Stockenstroom area where these farms and respondents are located.


4.3.1 Respondents level of education

Table 4.1 below reveals that 40% of the respondents had a secondary level of education followed by 37% who had a primary level. Respondents with no education represented 17% of all respondents. Tertiary level of education accounted for 6% of all respondents. Age group 31 to 35 years was the most educated group with two respondents having a tertiary qualification and 36 years and up being the least educated group. Age group 26 to 30 years had the highest number of respondents with secondary education which ranges from grade eight to twelve. The group with the youngest respondents namely 20 to 25 years showed that 50% of respondents within this age group had a secondary level education.

Overall, 46% accounted for respondents with secondary and tertiary education who were able to read and understand the pesticide label and 54% were unable to read the pesticide label. It can therefore be concluded from this result that, the majority of the respondents had primary or no education. This stance of education suggested that 54% of respondents were not able to read and interpret the pesticide label. Training in the safe use of pesticide could be rendered to the 46% educated respondents and the remaining 54% of respondents could encounter learning problems. It could therefore be suggested that, the educated group of respondents could help their peers who were less educated with the application and understanding of the safe use of pesticide training content. London and Baile (2001) supported this finding and stated that training difficulties were encountered with farm workers especially in the settings of low education.
Table 4.1. Education levels of respondents (n=30)

<table>
<thead>
<tr>
<th>Respondents’ age groups</th>
<th>No education</th>
<th>Primary level</th>
<th>Secondary level</th>
<th>Tertiary level</th>
<th>Number of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 – 25</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>26 – 30</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>31 – 35</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>36 +</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
</tbody>
</table>

4.3.2 Respondents knowledge of pesticide colour labels

SANS 10206 (2005) made it mandatory that all pesticide workers should undergo training about the meaning of the signs and the labels on pesticide containers. All respondents (100 %) interpreted the red colour on the pesticide label correctly and as indicative of a dangerous pesticide (Table 4.2). This easy interpretation of the red colour band by all respondents could be attributable to the red colour which is universally used within South Africa for denoting danger. Although the age group 20 to 25 is the youngest and third most educated, it showed a 100% lack of knowledge of other three pesticide label colour bands. This scenario was due to inexperience in handling pesticides and lack of training in judicious use of pesticides. This lack of knowledge rendered this group as high risk to handling pesticide which could inadvertently lead to poisoning. Forty four percent within age group 26 to 30 showed knowledge of the meaning of the yellow colour band and only a third of the respondents in age group 31 to 35 year indicated knowledge of the meaning of yellow, blue and green colour bands. The latter group showed that 17 % of the respondents in this age group knew the meaning of other colour bands on pesticide labels. Due to the knowledge of colour bands this group possessed, it rendered itself a low risk group to pesticide poisoning provided other precautionary personal protective
measures are practised during pesticide handling. This result showed that knowledge and interpretation of pesticide colour bands by the two oldest age groups came with age and long farm pesticide work service (Ajayi and Akinnifesi, 2007). The younger groups lacked this experience hence they displayed a lack of knowledge in interpreting other pesticide colour bands.

It can be suggested that old employees with experience and long farm work service should give pesticide colour band guidance to the young inexperienced employees and encourage them by exemplary actions to exercise safe handling of pesticides. This conduct would in turn reduce the risk of pesticide poisoning among all employees.

Table 4.2. Respondents knowledge of pesticide colour bands (n=30)

<table>
<thead>
<tr>
<th>Age group</th>
<th>Red label</th>
<th>Yellow label</th>
<th>Blue Label</th>
<th>Green label</th>
<th>Total respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-25</td>
<td>Yes 6</td>
<td>No 0</td>
<td>Yes 0</td>
<td>No 6</td>
<td>6</td>
</tr>
<tr>
<td>26-30</td>
<td>Yes 9</td>
<td>No 0</td>
<td>Yes 4</td>
<td>No 5</td>
<td>9</td>
</tr>
<tr>
<td>31-35</td>
<td>Yes 9</td>
<td>No 0</td>
<td>Yes 3</td>
<td>No 6</td>
<td>9</td>
</tr>
<tr>
<td>36+</td>
<td>Yes 6</td>
<td>No 0</td>
<td>Yes 1</td>
<td>No 5</td>
<td>6</td>
</tr>
</tbody>
</table>
4.3.3 Access to pesticide

Table 4.3 shows that 77% of all respondents have unlimited access to pesticides. Age group 31 to 35 years showed the highest number of respondents (27%) who had unlimited access to pesticides followed by age group 26 to 30 years. These results had a clear implication in that; a total of 23 out of 30 respondents had access to pesticides. This is not desirable and it presented a risk of increasing the chances of pesticide contact with respondents which might lead into irresponsible use of these chemicals by farm workers. The South African National Standard 10206 (2005) stipulated pesticide storeroom keeper to be the only person with pesticide access in the farm pesticide storeroom. From this result it can therefore be expected that poisoning incidences and pesticide related illnesses will be prevalent in these two groups especially if proper wearing of personal protective equipment was not practiced.

**Table 4.3.** Access to pesticides in the store room (n=30)

<table>
<thead>
<tr>
<th>Respondents’ age groups</th>
<th>Respondents with pesticide access</th>
<th>Respondents with no pesticides access</th>
<th>Total number of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 – 25</td>
<td>4</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>26 – 30</td>
<td>6</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>31 – 35</td>
<td>8</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>36 +</td>
<td>5</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>7</td>
<td>30</td>
</tr>
</tbody>
</table>
4.3.4 Pesticide work related duties

The statistical analysis revealed that there was a significant difference $p < 0.001$ between those respondents who performed pesticide related duties and those who did not. There were 19 out of 30 respondents who performed pesticide related duties ranging from spraying pesticide in orchards to burning empty pesticide containers (Table 4.4). It was in age group 31 to 35 year where the highest number (23 %) of respondents who performed pesticide related duties was indicated followed by age group 26 to 30 years with 20 % of respondents.

The youngest age group namely 20 to 25 years showed the least number (7 %) of respondents who performed pesticide related duties. The result of this study showed that it was older employees who were performing pesticide related duties on these farms and the majority of younger employees were engaged in non pesticide related farm chores. This pattern of performing pesticide related duties could be due to the rich experience the older employees had in pesticide application and the thoroughness they exercised in executing these operations. This finding also implied that, health problems could be prevalent in the older respondents due to performing pesticide related work on farms and long exposures to pesticides.
Table 4.4. Various pesticide related duties performed by respondents (n=30)

<table>
<thead>
<tr>
<th>Respondents’ age groups</th>
<th>Spray pesticide</th>
<th>Mix pesticide</th>
<th>Assist in pesticide spraying operation</th>
<th>Tractor driver, pesticide sprayer</th>
<th>Carry and burn empty pesticide containers</th>
<th>Total Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 – 25</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>26 – 30</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>31 – 35</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>36 +</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

*Means were separated using sed test at p< 0.001

### 4.3.5 Personal safety

Table 4.5 shows that twenty five respondents out of thirty wore personal protective equipment when handling pesticides. The age group 36 years and up showed a 100 % compliance with personal safety. Age groups 20 to 25 and 26 to 30 years were the second highest with 83 % of respondents respectively who complied with personal safety standards. However, 17 % of all respondents did not wear personal protective equipment when performing pesticide related duties. It was in the age group 31 to 35 years where 10 % of the respondents showed non compliance to personal safety. Since chlorpyrifos can enter the body through the skin, lack of personal protective equipment rendered the 10 % of respondents within age group 31 to 35 years vulnerable to pesticide exposure which can lead to poisoning. The wearing of personal protective equipment is stipulated as mandatory on the chlorpyrifos pesticide label and as a basic requirement which must be satisfied before handling the pesticide in order to prevent human poisoning. In a study conducted among vineyard and fruit pesticide operators in Turkey in the province of Izmir,
it was found that less than 60% of the respondents followed the directions on the pesticide container (Isin et al. 2006). It is also a requirement in South Africa as per guidance from South African National Standards 10206 (2005) that all persons involved in the handling of pesticides should be aware of the hazards involved in the use of pesticides and the wearing of personal protective clothing. It can be expected that there would be higher incidences of poisoning in age group 31 to 35 years compared to those groups which took the correct necessary precautions before handling pesticide.

Table 4.5. Personal protective equipment worn by respondents (n=30)

<table>
<thead>
<tr>
<th>Respondents’ age groups</th>
<th>Respondents who wear PPE</th>
<th>Respondents who do not wear PPE</th>
<th>Total number of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 – 25</td>
<td>5</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>26 – 30</td>
<td>8</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>31 – 35</td>
<td>6</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>36 +</td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>5</td>
<td>30</td>
</tr>
</tbody>
</table>

4.3.6 Health status of respondents

In Table 4.6 fourteen out of thirty respondents suffered from some illness. This is a high number in a group of thirty respondents and represented 47% of the respondents. Two age groups namely; 31 to 35 and 36 years and up, showed the highest number of respondents with body ailments. The two groups were made up of respondents who performed pesticide related work for more than five years. The illnesses that they
suffered from could be attributable to exposures to pesticide over a long period of time. The younger two groups had showed the lowest number of respondents with ailments. This youngest groups’ stance could be attributable to not performing pesticide related work, and those who performed pesticide related work had short time exposure to pesticides due to the short work service they had on these farms. From this result, it can be concluded that, pesticide related ailments tended to be evident in those respondents who had been exposed to pesticide for five years and longer.

Table 4.6. Health status of respondents (n=30)

<table>
<thead>
<tr>
<th>Respondents’ age groups</th>
<th>Respondents with illness</th>
<th>Respondents with no illness</th>
<th>Total number of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 - 25</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>26 – 30</td>
<td>1</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>31 – 35</td>
<td>5</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>36 +</td>
<td>5</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14</strong></td>
<td><strong>16</strong></td>
<td><strong>30</strong></td>
</tr>
</tbody>
</table>

4.3.7 **Respondents' illnesses and duration**

Age groups 31 to 35 and 36 years and up were the two groups with the highest count of respondents who suffered from illnesses (Table 4.7). These two groups represented a third of the total respondents who had participated in this study. The common illnesses that were found among the two groups were dizziness, persistent cough, short breath, blurred vision, nausea, back ache and sweating at night. These illnesses were identical to the symptoms of human pesticide poisoning. The National Pesticide Telecommunications
Network (NPTN) (1999) listed acute chlorpyrifos poisoning symptoms as; dizziness, blurred vision, pinpoint pupils, nausea, head ache, salivation, sweating, twitching of eye lids and muscle pains. Table 5.7 indicates respondents within the age groups 31 to 35 and 36 years and up as the respondents who suffered the most from these ailments. These respondents had the longest service on these farms and had been performing pesticide work related duties for more than five years.

Table: 4.7. Respondents illnesses and duration (n=30)

<table>
<thead>
<tr>
<th>Respondents’ age groups</th>
<th>Respondents with illness</th>
<th>Illness description</th>
<th>Duration of illness (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 – 25</td>
<td>3</td>
<td>Persistent cough, back ache and nausea</td>
<td>2</td>
</tr>
<tr>
<td>26 – 30</td>
<td>1</td>
<td>Back ache</td>
<td>5</td>
</tr>
<tr>
<td>31 – 35</td>
<td>5</td>
<td>Short breath, dizziness, persistent cough and back ache</td>
<td>2 – 6</td>
</tr>
<tr>
<td>36 +</td>
<td>5</td>
<td>Nausea, dizziness, blurred vision, cough and sweating</td>
<td>7 – 10</td>
</tr>
</tbody>
</table>

4.4 Face to face interviews with health professionals

The information received at Balfour Clinic revealed that from December 2008 to July 2009 four poisoned farm workers were treated in this clinic. These patients attempted suicide by drinking liquid pesticide. Out of four pesticide poisoning incidences treated in this clinic, two were fatalities. Males are the ones who poison themselves. The ages of the patients admitted for pesticide poisoning treatment was from 23 to 48 years. There was one patient for age group 20 to 25 years, two patients for age group 26 to 30 years
and one patient for age group 36 years and up. It was evident from this interview that poisoning cases were prominent in the age group of 26 to 30 years. Generally, farm workers visited this clinic for the treatment of illnesses such as persistent cough, high blood pressure, blurred vision, fatigue, nausea and vomiting and cyclical head-aches (Nursing sister, verbal communication, 2009).

In Fort Beaufort Hospital it was reported that most pesticide poisoning incidences received from Balfour Clinic were caused by domestic problems, alcohol and drug abuse especially cannabis. Fort Beaufort Hospital work hand in hand with Tower Psychiatric hospital which conducted psychiatric counselling to patients and offered training in self help skills in order to change behaviour and to give meaning to life for all admitted psychiatric patients. From this information it can be concluded that, access to pesticide is a huge problem in this vicinity and that all patients who were treated at Balfour Clinic, poisoned themselves with pesticides obtained from surrounding citrus farms. Confinement of pesticides to farm pesticide storerooms and access restriction of farm workers to pesticides is indispensable in reducing pesticide accessibility which will curb deliberate human pesticide poisoning.

4.5 Observation of pesticide personnels’ actions during a chlorpyrifos spray operation

Actions of the personnel involved in the execution of chlorpyrifos spray operation were carefully observed in order to establish the practise of judicious use of pesticides in accordance with EuroGAP standards of handling pesticides. The three farms were part of a conglomerate which subscribed to the standards of EuroGAP in order to be allowed to export oranges to European markets. This subscription with EuropGAP had assisted
these farmers to upskill their work force on farms in the responsible usage of pesticides and also made farmers to observe pesticide storage standards on farms as stipulated by EuroGAP.

4.5.1 Storage of pesticides on farms

In all the three farms, pesticides were correctly stored in pesticides storage rooms. On the outside wall above the door frame, all pesticide storerooms were vividly labeled in black against a yellow background “POISON STORE” to inform everybody on the farm. All pesticide storerooms were locked using a padlock. This practise conforms to the South African standard of keeping pesticides on farms. There was no proper lighting inside the pesticide storeroom which made it difficult for everyone to read the pesticide labels inside the storeroom. Lack of lighting inside a pesticide storeroom can cause confusion between herbicides and pesticides which can have devastating outcomes for the farm owner. Pesticides were not packed on shelves and not according to their level of toxicity either and there was no mini storage facility inside the storeroom in which to keep all red colour banded pesticides. This is an undesirable behaviour as it contravenes the guidance SANS 10206 provided for keeping of pesticides on farms.

4.5.2 Temporary pesticide storerooms

Farm A had a temporary storeroom in one of its orchards. Pesticides were temporarily stored and locked in this storeroom in order to be closer to the orchard that was being sprayed. At the end of the day’s work, the pesticides in the temporary pesticide storeroom were carried back to the farm pesticide storeroom for safe keeping. This is a comendable behaviour which prohibited unauthorised persons to access these
chemicals. Farms B and C had no temporary storage facilities and pesticide being used were put under a tree in an orchard. This practise could increase the level of access to pesticides by non authorised persons and could aggravate the problem of farm suicide incidences and human pesticide poisoning.

4.5.3 Personal protective equipment

The personal protective equipment worn by farm workers who assisted during the spray operation was rubber boots only. These boots were incorrectly worn, that is, the pants were inside the boots instead of pants hanging outside and over the boots. The pesticide operator who undertook the chlorpyrifos spray operation wore an orange cotton overall, a respirator, rubber boots and a hat made of wool (Plate 4.2). No hand - gloves were worn and the overall was not water tight. The personal protective clothing worn by farm workers was inadequate and provided insufficient protection from the spray mixture. This non compliance to personal safety made the farm workers to be at high risk of getting poisoned especially through the skin. The failure to adhere to the basic personal protection could be blamed on the supervisor and farm workers themselves in that; they were aware of the toxicity and harmfullness of the pesticide to their health and environment. This scenario clearly highlighted the failure of the Departments of Agriculture and Health in enforcing compliance to the contents of the Occupational Health and Safety Act as well as South African National Standard 10206 (2005). Training in the safe use of pesticide would definitely play a vital role in giving guidance to the farm workers to wear the correct personal protective clothing whenever they handle pesticides and such personal protective equipment be worn in the correct manner.
Plate 4.2. Pesticide operator showing personal protective clothing during chlorpyrifos spray operation

4.5.4 Spill kit

During the pesticide mixing process, a spill kit which can be used to clean up any spillages that might occur during mixing was unavailable. The spillage which happened at farm A was never cleaned and was ignored for the soil to absorb it (Plate 3.8). This ignorance of spillages could lead to environmental pollution and poisoning of people and animals. The farm owners must source a pesticide spill kit which must be made available
at all times during pesticide handling operations. Farm workers must be trained in the method of cleaning up a pesticide spillage using a pesticide spill kit.

4.5.5 First aid kit and other equipments

First aid kit was unavailable during the spray operation. According to the South African National Standard of 2005, clean drinkable water, eye wash bottle, a blanket, liquid soap and a first aid kit must be made available during the course of a spray operation. Since this was not the case, farm workers from all three farms stood a risk to be poisoned by the pesticide with no basic help at hand.

4.5.6 Cleansing after spray operation

The three farms were not equipped with bathroom facilities which can be used by farm pesticide operators at the end of a spray operation. During lunch breaks, operators had been seen washing their faces and hands from the same water point they used for pesticide mixing. At the end of each working day, pesticide operators left the farm for their homes wearing pesticide contaminated clothes. This behaviour had put the families of these farm workers at risk of getting poisoned from contaminated clothes and also from the water in which they washed the contaminated clothes and overalls. In order to mitigate poisoning of farm pesticide workers' family members, farm owners should be compliant to the Occupational Health and Safety (OHS) Act by building bathroom facilities in which pesticide operators could wash themselves before going home.
4.5.7 Pesticide container management

The disposal of empty containers is a huge challenge to citrus producing farmers because South Africa does not have a pesticide incinerator. On these farms, empty containers were rinsed and burned. This practise is in contrary to the South African National Standard 10206 of 2005 which declared burning of empty pesticide containers illegal in South Africa.

4.6 Farm workers’ health records

These records (not shown for ethical reasons) revealed that the most prevalent illnesses which were treated at Balfour Clinic were persistent cough, back aches, chest pains, short breath, dizziness and cyclical headaches. In farm A, one record showed that one farm worker was once treated for hallucinations. These symptoms were identical to those mentioned in section 2.10.3 of this study which were caused by chlorpyrifos poisoning.
CHAPTER 5
SUMMARY AND CONCLUSIONS

5. Introduction

This chapter gives a summary and conclusions drawn from the results of experiments and data analysis performed for this study. It also lists further research suggestions which can be undertaken in order to pursue this study further.

5.1 Chlorpyrifos effectiveness

Chlorpyrifos application on orange trees at farm A and B revealed that *H. armigera* larvae population was reduced by 95 % and 100 % respectively. It was found at farm C where no chlorpyrifos was applied on orange trees that the pest population had increased by 220 % over a period of three days. These results confirmed that chlorpyrifos application on orange trees brought about suppression of *H. armigera* larvae population. It can therefore be concluded that chlorpyrifos was effective in suppressing *H. armigera* larvae population on orange trees.

5.2 Orange yields

Farms A and B which were sprayed with chlorpyrifos pesticide showed high yields of 3409 and 2847 of oranges respectively. Farm C showed the lowest yield of 1290 oranges which represented a yield decline of 264, 3 % compared to farm A. The difference in
results of orange yields suggested that, trees which were sprayed with chlorpyrifos brought about high yields as compared to untreated trees. It could be concluded from the results obtained that application of chlorpyrifos on orange trees brought about a decline in the destructive activities of *H. armigera* larvae and thus resulted in increased orange yields.

The results should however be treated with caution as there were several factors that could potentially have an influence in the data. These factors are shown in section 3.9; (i) homogeneity of the orchards in terms of microclimatic conditions. This was a limitation as this could not be established accurately and (ii) operational and management needs could not enable use of each orchard for all three treatments. Issues of multiplication of pests were of concern where certain portions of the orchards were not to be sprayed. The researcher could operate under existing farm programmes. In fact, the researcher participated and observed pesticide activities as they are normally carried out. On the other hand, the results provided a true picture of the pesticide usage situation in some small to medium scale farms of black emerging farmers.

### 5.3 Health of pesticide operators

Data analysis indicated that 47% of the respondents suffered from different illnesses such as persistent cough, back ache, nausea, short breath, dizziness, blurred vision and sweating at night. These illnesses can be classified as pesticide related illness because they are identical to pesticide poisoning symptoms. The analysis of data revealed that it was those farm workers in the age group of 31 to 35 years and up who suffered the most from pesticide related illnesses. This situation is due to the length of time these
respondents had been exposed to pesticides and the fact that they have been working on these farms longer than the younger age groups which suffered much less from these illnesses. Health records also confirmed the health status of respondents as the true reflection of the data analysis results obtained from farm workers’ questionnaires. Visual observations of personnel involved during execution of chlorpyrifos spray mixture also indicated irresponsible use of chlorpyrifos which can exacerbate human pesticide poisoning. The current status and findings gave adequate reason to worry and to think of finding ways and means of developing intervention programmes to reduce misuse of pesticides on the farms.

5.4 Conclusions

The results found from this study were a revelation and are concluded by the following statements:

A. Pesticide usage

- Chlorpyrifos application on orange trees at farm A and B reduced *H. armigera* larvae population by 95 % and 100 % respectively.

- It was found at farm C where no chlorpyrifos was applied on orange trees that *H. armigera* population had increased by 220 % over a period of three days.

- Farm orchards which were sprayed with chlorpyrifos pesticide showed high yields of 3409 and 2847 of oranges respectively. Control of *H. armigera* pest using
chlorpyrifos had resulted in decreased damages and destruction to oranges and thus high orange yields were realised.

- Farm C showed the lowest yield of 1290 oranges which represented a yield decline of 264, 3% compared to farm A. Non application of chlorpyrifos on orange trees resulted in high damages and destruction to oranges caused by *H. armigera* larvae and thus low orange yields were realised.

### B. Farm operators’ health

- This study revealed that 14 out of 30 farm pesticide operators suffered from pesticide related illnesses. This scenario was aggravated by lack of training in the judicious use of pesticides.

- The study also showed that it was those pesticide operators in the age group of 31 to 35 years and up who suffered the most from body ailments. The pesticide operators in this age group had a pesticide exposure of more than 5 years.

### C. Recommendations

- Non-governmental organisations are active in bringing about awareness of the dangers of pesticides within the farming communities. More work is still needed in this regard as it is evident that a lot of farms do not comply with pesticide regulations.
• Government’s contribution to enforce compliance to South African National Standard 10206 of 2005 in order to curb human pesticide poisoning is not satisfactory. A national study of small to medium scale farms’ usage of pesticides should be commissioned urgently to measure the magnitude of pesticide misuse and effect on health of farm operators.

• Revision and implementation of the new Act 36 of 1947 by the government is vital for better management of pesticides and enforcement of compliance by all those who use pesticides.

D Further studies

This study had unveiled the necessity for further research on issues which became of concern and interest such as:

• There is a need to investigate sustainable alternative ways of pest control such as Integrated Pest Management which will be less dangerous to the health of farm workers and the environment.

• A further study needs to be conducted for wider coverage to determine the extent of pesticide poisoning to farm workers in the Province of the Eastern Cape.

• More probing in conjunction with the medical profession on the health of farm communities is needed as the number of people at risk is significant.
References


ECOBICHON, D. J. (2001). Pesticides use in developing countries. Department of Pharmacology and Toxicology. Queen’s University, Kingston, Canada.


GOVERNMENT GAZETTE No. 28711 (2006), Pretoria, South Africa


SPEECH BY THE MINISTER OF DEPARTMENT OF LABOUR at the Winelands Conference on 08 October 1999. Cape Town, South Africa.

STATISTICS SOUTH AFRICA (2002). Agricultural census of the Eastern Cape Province. Pretoria, South Africa


www.EzinetArticle.co/?expert=Michael_Russell. accessed in April, 2010


Appendix A

CONSENT FORM

TO WHOM IT MAY CONCERN

I…………………………………………………………………………………………………………………………
the undersigned, an employee at the farm mentioned below, hereby allow Mr. KJ
Siyoko to peruse my health records at Balfour Clinic in the Eastern Cape Province for the
purpose of his Master of Science in Agriculture studies with the University of South
Africa.

Name of employee …………………………………………………………………………………………………

Farm name ……………………………………………………………………………………………………………

Age …………………………………………………………………………………………………………………

Signature ……………………………………………………………………………………………………………

Date …………………………………………………………………………………………………………………

Witness ……………………………………………………………………………………………………………

Signature ……………………………………………………………………………………………………………

Date …………………………………………………………………………………………………………………
## Appendix B

### SURVEY QUESTIONNAIRE

#### PERSONAL DETAILS

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respondent No.</td>
<td></td>
</tr>
<tr>
<td>1. Age</td>
<td></td>
</tr>
<tr>
<td>2. Occupation</td>
<td></td>
</tr>
<tr>
<td>3. What level of schooling do you have?</td>
<td></td>
</tr>
<tr>
<td>4. Are you married?</td>
<td></td>
</tr>
<tr>
<td>5. How many children do you have?</td>
<td></td>
</tr>
<tr>
<td>6. Do you work with pesticides?</td>
<td></td>
</tr>
<tr>
<td>7. If yes, for how long?</td>
<td></td>
</tr>
<tr>
<td>8. What type of work do you do during a spray season?</td>
<td></td>
</tr>
<tr>
<td>9. Do you live with your family in the same house?</td>
<td></td>
</tr>
<tr>
<td>10. Were you trained on how to use pesticides responsibly?</td>
<td></td>
</tr>
<tr>
<td>11. If Yes, in which year?</td>
<td></td>
</tr>
</tbody>
</table>
SAFETY

12. Do you undertake a blood test to determine pesticide poisoning?

13. If yes, when last was your blood tested?

14. Did you see your blood test results?

15. If NO, what prevented you from seeing your blood test results?

16. How many times a year do you undertake a blood test?

17. Do you wear personal protective equipment when working with pesticides?

18. Who provides you with personal protective equipment?

19. Do your personal protective clothing come in pairs?

20. Is the protective gear in good state of repair?

21. If No, which protective gear is in the bad state of repair?

22. Describe how you wear your overall, boots and gloves

23. At what time of the day do you start spraying orchards?

24. How many operators spray one orchard at the same time?

25. Does your supervisor visit you in the orchard during a spray operation?

26. If NO, how do you communicate with him/her during a spray operation?
<table>
<thead>
<tr>
<th></th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>Do you keep temporary decontamination units in orchards during pesticide application operation?</td>
</tr>
<tr>
<td>28</td>
<td>Where do you keep pesticides on this farm?</td>
</tr>
<tr>
<td>29</td>
<td>How do you make sure that the place where you keep pesticide is secured?</td>
</tr>
<tr>
<td>30</td>
<td>How many people are trained in first aid on your farm?</td>
</tr>
</tbody>
</table>

**HEALTH**

<p>| 31 | Before going to spray in the orchard, who checks that you have or have not worn personal protective equipment? |
| 32 | Where do you mix a pesticide that is going to be sprayed in the orchard? |
| 33 | What personal protective equipment do you wear during mixing of pesticide/s? |
| 34 | When spraying in the orchard, what personal protective equipment do you wear? |
| 35 | Have you ever been poisoned by a pesticide?                              |
| 36 | If yes, how did the poisoning incident happen?                            |
| 37 | Do you know of any person/s who died because of pesticide poisoning?      |
| 38 | If yes, how many do you know of?                                         |</p>
<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>39. How did such incident happen?</td>
<td></td>
</tr>
<tr>
<td>40. Do you suffer from any illness?</td>
<td></td>
</tr>
<tr>
<td>41. If yes, describe illness</td>
<td></td>
</tr>
<tr>
<td>42. For how long have you been suffering from this illness?</td>
<td></td>
</tr>
<tr>
<td>43. How many times have you visited a doctor/clinic/hospital or witch doctor because of this illness?</td>
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<tr>
<td>44. Describe the health of your family members</td>
<td></td>
</tr>
<tr>
<td>45. After a spray operation, what is the first thing that you do?</td>
<td></td>
</tr>
<tr>
<td>46. Who washes your clothes after a spray operation?</td>
<td></td>
</tr>
<tr>
<td>47. Where are your clothes washed after a spray operation?</td>
<td></td>
</tr>
<tr>
<td>48. What do you do with the dirty wash water after your clothes have been washed?</td>
<td></td>
</tr>
<tr>
<td>49. What do you do with pesticide leftovers?</td>
<td></td>
</tr>
<tr>
<td>50. On your farm, where do you wash and clean your tractor drawn spray equipment?</td>
<td></td>
</tr>
<tr>
<td>51. Do you read a pesticide label?</td>
<td></td>
</tr>
<tr>
<td>52. How do you identify pesticides?</td>
<td></td>
</tr>
<tr>
<td>53. Can you be able to distinguish between pesticide containers that are most toxic and those that are less toxic?</td>
<td></td>
</tr>
</tbody>
</table>
54. What colour bands are pesticides that you often work with?

55. What do the following colour bands mean?
56. Red colour band means
57. Yellow colour band means
58. Blue colour band means
59. Green colour band means
60. What symbol is used on the pesticide label for a very toxic pesticide?
61. What colour band is the pesticide you use for controlling American bollworm?
62. What do we call the little pictures that we find within a colour band of a pesticide?
63. What is the purpose of the little pictures that we find within a colour band of a pesticide?

CONTAINER MANAGEMENT

64. What is the first thing that you must do to an empty pesticide container?
65. How do you dispose of empty pesticide containers?

FARM WORKERS RIGHTS

66. Have you heard of South African National Standards 10206?
67. If yes, what does this standard entail?
68. What do you think your rights are as a farm worker?
Appendix C

Guiding questions for health professionals:

1. Have you ever treated patients with pesticide poisoning?
   ........................................................................................................................................
   ........................................................................................................................................

2. From Dec 2008 to July 2009 how many cases of pesticide poisoning have you attended to?
   ........................................................................................................................................
   ........................................................................................................................................

3. How many of the pesticide incidences you treated terminated in death?
   ........................................................................................................................................
   ........................................................................................................................................

4. What population age group had been treated for pesticide poisoning?
   ........................................................................................................................................
   ........................................................................................................................................

5. What sex of population would you consider as prone to pesticide poisoning?
   ........................................................................................................................................
   ........................................................................................................................................

6. What types of illnesses do farm workers get treated for?
   ........................................................................................................................................
   ........................................................................................................................................
7. Is there any support that you get from another health facility for treating pesticide poisoned patients?

8. What reasons do you think lead farm workers to poison themselves with pesticides?

9. Is there any counselling or training given to victims of pesticide poisoning?