Pest Risk Analysis on hand luggage at OR Tambo International Airport: A case study of flights from Cameroon, India and Kenya

by

Robert Mooketsa Ramasodi

Submitted in partial fulfillment of the requirements for the degree

Magister Institutionis Agrariae: Plant Production (Agronomy)

Department of Plant Production and Soil Science

in the

Faculty of Natural and Agricultural Sciences

University of Pretoria

Pretoria

South Africa

July 2008

Supervisor: Prof. P S Hammes

Co – supervisor: Mr. M A Holtzhausen

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ABBREVIATIONS

ALOP – Appropriate Level of Protection

CPC - Crop Pest Compendium

EPPO – European Plant Protection Organisation

FAO – Food Agriculture Organisation

FHAT – Forced Hot Air Treatment

HWT – Hot Water Immersion Treatment

IPPC – International Plant Protection Convention

ISPM – International Standard for Phytosanitary Measures

Kg – kilogram

MPL – Maximum Pest Level

MT – metric ton

NPPO – National Plant Protection Organization

PRA – Pest Risk Analysis

SOP – Standard Operating Procedure

Temp – temperature

t – tonne

VHT – Vapour Heat Treatment

WTO-SPS - The World Trade Organisation's Agreement of the Application of Sanitary and Phytosanitary Measures

°C – Degree Celsius

% - percentage

< - greater than

DECLARATION

I, Robert Mooketsa Ramasodi, hereby declare that this dissertation for the degree M. Inst. Agrar: (Plant Production) Agronomy at the University of Pretoria is my own work and has never been submitted by myself at any other University. The research work reported is the result of my own investigation, except where acknowledged.

R.M. Ramasodi

ABSTRACT

A Pest Risk Analysis was conducted on commodities imported as hand luggage from Cameroon, India and Kenya at O.R. Tambo International Airport. The initiation phase indicated that fruit, and to a lesser extent vegetables, are often imported concealed in hand luggage and not declared for inspection. Such undeclared commodities pose a risk to the South African agricultural industry and environment as it may serve as a pathway for quarantine pests.

The qualitative pest risk assessment conducted on the commodities intercepted indicated that the risk is high, with the commodities serving as pathways for quarantine pests including insects, bacteria, mites, fungi, viruses and weeds. *Bactrocera* fruit flies were identified as a specific high risk and were further subjected to a quantitative pest risk assessment.

Mitigation treatments for fruit flies were evaluated for efficacy and effect on the quality of the fruit. Hot water immersion treatment was deemed to be an effective mitigation treatment for fruit flies. This treatment on fruit flies was found effective at pulp temp of 46°C and 47°C where the pulp temp is held for 10 and 12 minutes respectively.

Keywords: pest risk analysis, pest risk assessment, quarantine pests, quarantine security, Bactrocera fruit flies; HWT.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

CHAPTER 1

GENERAL INTRODUCTION

The World Trade Organisation that came into effect after the Uruguay Round of world trade negotiations of the then General Agreement of Tariffs and Trade (GATT) regulates international trade (WTO Agreements Series, 1998). This Organization formalised about 60 agreements, annexes, decisions and understandings. One of these agreements is the Agreement of the Application of Sanitary and Phytosanitary Measures (WTO-SPS Agreement), which came into force on 1 January 1995 (WTO-SPS Agreement Series, 1998; www.wto.org). The series states that the purpose of the WTO-SPS Agreement is to protect human, animal and plant health and life. The WTO-SPS Agreement recognizes three standard setting bodies, the (1) International Plant Protection Convention (IPPC), (2) the Office International des Epizooties (OIE) and (3) Codex Alimentarius. These three organizations address the three areas of responsibilities of the WTO – SPS Agreement, the plant, animal and human health and life respectively (WTO Agreements Series, 1998).

The IPPC is the technical standard setting body for plant health matters, using scientifically based inputs as a decision making mechanism for the importation and exportation of plants, plant products and other regulated articles (www.ippc.int).

The IPPC publishes standards in a series known as the International Standard for Phytosanitary Measures (ISPMs) and member countries use the ISPMs as guidelines to ensure harmonized phytosanitary measures that are least restrictive to trade (www.ippc.int). Within the IPPC, Pest Risk Analysis (PRA) is considered the scientific process that ensures that the objectives of the IPPC are met (IPPC, 1995; IPPC 2004a). Non-member countries are also encouraged to adopt the ISPMs for harmonisation of regulatory plant health matters (IPPC, 1997). The Republic of South Africa is a signatory member of the IPPC (www.ippc.int).

The Convention on Biological Diversity (CBD) addresses aspects of biological diversity, genetic resources, species, and ecosystems (www.biodiv.org). CBD addresses invasive alien species, which includes regulated pests as defined by the IPPC. Articles 4(b) and 8(h) of the CBD oblige member countries to prevent the introduction of pests into their neighbour's territories as well as spreading these pests within their own territory.

In the Republic of South Africa the potential introduction of pests is administered through the Agricultural Pests Act, 1983, Act no. 36 of 1983 (www.nda.agric.za). The Act authorises the import and national control measures for controlled goods. It also prescribes the ports of entry through which controlled goods may be imported. Section 3 of this Act, compels imported controlled goods to be declared and be presented to the executive officer who then will inspect or sample the controlled goods as necessary. The inspection and sampling are for regulated pests. Regulated pests include both quarantine and regulated non quarantine pests (IPPC, 2005a).

These international agreements, conventions and the national legislation regulate trade in plants, plant products and other regulated articles. The principles and prescripts provided for by these agreements, conventions and legislation, will be used to evaluate the importation of controlled goods in hand luggage.

A significant number of plant pests entering countries are human assisted either through luggage, commercial consignments or as hitchhikers (Maynard *et al.,* 2004). This investigation assumed that some travellers from Cameroon, Kenya and India will not declare controlled goods in their hand luggage. It is important to quantify such goods that are not declared and therefore illegally imported in terms of the Agricultural Pests Act, 1983. Of all pests, few have the potential international market and world trade impact of fruit flies (Peńa *et al.*, 1998). Therefore this investigation also subjected fruit flies to a pest risk analysis. The purpose of this investigation was to:

- Profile and conduct a pest risk assessment on plant and plant products imported from Cameroon, Kenya and India as possible pathways for quarantine pests.
- Identify probable pathways for the *Bactrocera* fruit flies from the passenger hand luggage from the targeted flights.
- Determine the probability of *Bactrocera* fruit flies entry, establishment and spread in South Africa.
- Evaluate probable phytosanitary management options for control of *Bactrocera* fruit flies.

CHAPTER 2

REVIEW OF LITERATURE

2.1 INTERNATIONAL TRADE

WTO-SPS measures were formulated to reduce protectionism in agricultural trade through the use of scientifically based decisions (James and Anderson, 1998). These measures while imposing least restrictive measures to trade must also protect the country from potential damage caused by entry, establishment or spread of pests (www.wto.org). The WTO-SPS gives effect to three types of actions that countries can adopt to manage risk: (1) selecting an appropriate level of protection (ALOP) by the member, (2) establishing SPS measures to achieve the ALOP deemed appropriate by the member (3) accepting measures established by other members as equivalent to its own (www.wto.org). Measures adopted by countries must be technically justified and based on a PRA (Matthews, 2004; www.wto.org). While the reasons for the existence of the WTO-SPS Agreement appear noble, Miljkovic (2005) argues that the decisions based on WTO-SPS measures are not entirely scientific, especially where emergency actions are taken on organisms not yet identified as quarantine pests through a PRA. While these measures create a sound balance between national policies, questions on the ability of the WTO to encourage rational frameworks for dealing with alien invasive species lack answers (Miller, 2003).

The other dimension is that as international trade regimes grow the stronger countries due to scientific resources of conducting PRA start to negatively influence trade with weaker countries by challenging the weaker countries' national legislation (www.tradelaw.net). The stronger countries with resources for conducting PRA's therefore dictate to the countries with lesser resources to accept their measures in trade. Hence some countries regard WTO-SPS measures as technical barriers to trade. Furthermore it is argued that SPS measures do not take cognisance of price increases due to embargoes (James and Anderson, 1998).

The IPPC succeeded the first International Plant Quarantine Agreement, the *Phylloxera vasatrix* Convention of 1881(Maynard *et al.*, 2004). The Agreement was drafted and ratified after *Phylloxera vasatrix* wiped out grapes in Australia and Europe. The objective of the IPPC is to secure common and effective action to prevent the spread and introduction of pests of plants and plant products and promote appropriate measures for their control (www.ippc.int). The IPPC has ISPMs which are used to harmonise trade between member countries. The Convention has different articles and of importance that guide member countries and harmonise the responsibilities. Article IV of the IPPC amongst others gives the countries the responsibilities of inspection, surveillance and conducting PRA (IPPC, 1997). It further specifies that such inspections be conducted by the National Plant Protection Organisation, which has duly authorized and competent officials.

Inspection on imported consignments is an integral part of the NPPO's responsibilities and obligations. The NPPO is supposed to have an import regulatory system that has a regulatory framework (legislation and regulations, standards, standard operating procedures (SOPs) and can effect phytosanitary management options of refused entry, treatment or destruction of the consignment as outlined in Article VII of the IPPC (IPPC, 2004b). The Agricultural Pests Act, (1983) provides for plants, plant products and other regulated articles to be declared at the port of entry. This Act is also aligned to Article VII of the IPPC with regards to phytosanitary management options. Each country has a sovereign right to protect its territories against the introduction of regulated pests, provided that these are scientifically justified and transparent (IPPC, 1997).

The biosecurity concept is about keeping out what is not present in an area and deciding what to do with existing undesirables (Rejmànek, 2000; Ferrar, 2004). Invasion of undesirables is a threat to biosecurity (Willis *et al.*, 2000). Quarantine pests are also undesirables and they are defined as pests of potential economic importance to the area endangered thereby and not yet present there, or present and not widely distributed and being officially controlled (IPPC, 2005). Quarantine is about the presence of a pest in one area against the absence of a pest in another area and the economic impact that the pest might have in an area if introduced (Heesterbeek and Zadoks, 1987). Quarantine pests may also be of detriment to the environment (IPPC, 2004a).

2.2 QUARANTINE MEASURES

To ensure that pests are not introduced and spread in areas where they are absent, phytosanitary measures are adopted. These measures are aimed at broadening of quarantine control beyond border control towards: (1) shared responsibility between countries (offshore) and inland (pest reporting), (2) early warning systems to detect early pest incursions and (3) early response plans and strategies (Nunn, 1997). The early response plans and strategies should include eradication programmes and contingency plans.

Phytosanitary measures are enforced using a continuum of activities that are distinguishable at three levels, (1) pre border, (2) border and (3) post border (Tanner, 1997). Such activities form the basis of the import regulatory system and are meant to prevent the introduction of quarantine pests and limit the entry of regulated non quarantine pests (IPPC, 2004b).

2.2.1 Pre border activities

Pre border activities are aimed at managing the risks before the consignment is imported into the country (Nunn, 1997). These activities are initiated through a PRA which is *inter alia* initiated by import of new regulated articles, change in legislation or interception of a new quarantine pest (IPPC, 1995; IPPC 2004a).

The PRA will, where the risk is manageable, recommend pest risk management options which are aimed at ensuring that the exporting country meets the importing countries' ALOP (www.wto.org). Options are diverse, ranging from integrated pest risk management, different levels of inspections, defined sampling units and regimes, pest free areas, including, country freedom from a pest, pest free places of production and production sites and areas of low pest prevalence (www.ippc.int). Where the ALOP cannot be achieved through the above mentioned options, then mitigation treatments can be considered (IPPC, 1995; IPPC, 2004a).

Early warning systems also form part of pre border activities, assessing risks around the globe and informing border personnel about impending risks (www.usda.gov). Pre border activities are in effect broadening of quarantine control beyond the importing country's border (Nunn, 1997). They are about ensuring that risk management becomes a shared responsibility between trading partners.

2.2.2 Border activities

Border activities are mainly concerned with documentation checks, phytosanitary inspection, release and detention of consignments (IPPC, 2004b). Inspection refers to an official visual examination of plants, plant products or other regulated articles to determine if pests are present (IPPC, 2005a). Testing is therefore viewed as a separate function from inspections.

Inspection also includes the visual examination of personal effects of passengers travelling internationally (IPPC, 2004b). Inspection at ports of entry is aimed at preventing entry of pests (pest exclusion) (Hollingsworth *et al*., 2003). Border inspections are the last attempt to ensure that quarantine pests are not introduced into a country (Hopper and Campbell, 1989).

To maximize the returns on border control, activities must be targeted at identified high risk material (Tanner and Nunn, 1998). Hand luggage has been identified as high risk material (Maynard *et al.*, 2004). Inspection measures of a country must not be more stringent for imports than applied locally (IPPC, 1997). It is generally accepted that while inspection offers economies of time in terms of labour and resources; it may be less accurate (Stonehouse *et al.*, 2003). There is also a general acceptance that some pests escape this system of inspection (Matthys and Burger, 1980). Inspection should therefore preferably be used in tandem with other phytosanitary actions (IPPC, 2002).

Where fruit consignments are infested, refusal of entry, treatment or destruction must be conducted in terms of Section 4 of the Agricultural Pests Act, (1983) and the exporting country must be informed by a notification of non compliance and interception (IPPC, 2001). Border activities are important for the pest exclusion and the inspection and sampling intensity must be adequately sensitive to detect pests (IPPC, 2005b).

2.2.3 Post Border Activities

Post border activities form the last area within the continuum and are aimed at quarantine pests that have eluded activities within pre border and border levels. This is the last stage and more costly than the first two stages which are basically preventative. These activities *inter alia* include surveillance and monitoring (Tanner, 1997). Post border activities are crucial to detect early incursions and establishment of pests. The biological process of colonization by exotic pests is divided into introduction, establishment, spread and naturalization (Kiritani, 1999). Through detection surveys early incursions of pests can be detected. Once a pest is detected, delimiting surveys must be conducted to establish the extent of the pest spread (IPPC, 1998). It is this delimiting survey that will identify the phytosanitary actions that are to be taken. When introductions occur, there are three actions that can be applied namely, ignore, contain or eradicate the introduced pest (Maynard *et al.*, 2004).

Early detections are very crucial for sustainable ecological and agro ecological systems. The surveillance and monitoring systems must be augmented by providing for early response plans. The early response plans encompass contingency plans and eradication programmes. Eradication programmes can only be implemented where it has been ascertained that it is economically feasible to conduct. Where pest establishment has been determined, pest reporting is done and the pest status of the country is amended accordingly (Nunn, 1997).

The ideal situation would be having strong pre border activities that will ensure the importation of controlled goods that are free from quarantine pests. Where the possibility of pests being imported exists, the border activities should have inspection and sampling regimes that will detect quarantine pests and therefore subject the controlled goods to phytosanitary management options. The post border activities are applied to ensure early detection of pests and the recommendation of early response options or eradication where feasible.

2.3 PEST RISK ANALYSIS

Where there is trade, there is risk, where there is risk; there is tolerance (Griffin, 2005). A PRA is used to scientifically justify this tolerance, which is an ALOP. A PRA is defined as the process of evaluating biological or other scientific and economic evidence to determine whether a pest should be regulated and the strength of any phytosanitary measures to be taken against it (IPPC, 1995; IPPC 2004a). It is concerned with the phytosanitary measures that can reduce the probability of a risk to an acceptable level by the importing country (www.tradelaw.net). Therefore a PRA is recognized as a formal decision making tool in international trade and has been used to target and reevaluate border programs (Nunn, 1997). A PRA can be initiated by a pathway or a pest (IPPC, 1996). A pathway refers to any means that allows entry or spread of a pest while a pest refers to any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products (IPPC, 2005).

PRA is divided into risk initiation, risk assessment and risk management (IPPC, 1995; IPPC, 2004a). The concept of PRA is also applied in general risk analysis which is divided also into three facets: (1) Risk Assessment – the process of identifying and estimating risks associated with a policy option and evaluating the likely consequences of those risks, (2) Risk Management – the process of identifying, documenting and implementing measures to reduce these risks and their consequences, (3) Risk Communication – the process of interactive interchange of information and views concerning risk between analysts and stakeholders includes import conditions for the commodity.

The Australian Nairn Review defines the principles of PRA as consultation, a scientific basis, transparency, consistency and harmonisation and subject to an appeal. Nunn (1997) added the other principle that a PRA must be subject to periodic review.

2.3.1 Pest risk initiation

Pest risk assessment deals with determining commodities to be subjected to a PRA (www.spc.int). The process then moves to pest categorization to evaluate the characteristics of a pest to determine whether it qualifies to be classified as a quarantine pest (IPPC, 2004a). This stage eliminates the unnecessary performance of a detailed PRA. The initiation as outlined can either be through pest or pathway (IPPC, 1995; IPPC, 2004a). For this study, the initiation is through the pathway. Aircraft hand luggage may serve as pathways for pests and has thus been targeted as a source of entry in an ecological risk assessment model (Landis, 2003).

The possibilities of finding agricultural commodities in an aircraft are 50% or lower (www.cast-science.org). Therefore aircraft as a carrier should be targeted for detection of agricultural commodities at ports of entry. The illegal import of fruit by passengers for instance increases the risk of introduction of quarantine pests especially fruit flies (Gupta and Ketharpal, 2005). As the amount of imported plants increases; the importance of plant quarantine also increases due to the increase in the number of potential pathways (Yamamura and Sugimoto, 1995). Regulated articles found in luggage are subjected to the second stage of PRA, pest risk assessment.

2.3.2 Pest risk assessment

Assessment identifies and estimates risks associated with pathways, with analysis on the consequences of taking these risks (Nunn, 1997). Pest risk assessment is divided into two steps; assessment of probability of introduction and assessment of potential economic impact (IPPC, 1995; IPPC, 2004a). Pest risk assessment has semi quantitative or quantitative approaches towards risk assessment can either deterministic or stochastic (Nunn, 1997). The deterministic approach assign a single number to each point in a scenario tree so that the assessment leads to a single value, ignoring variation within a natural system while the stochastic approach assigns each point a value that takes into account variation (Nunn, 1997).

(a) Geographical and regulatory criteria

The regulatory criteria emanate from a pest being a quarantine pest or a non quarantine pest (IPPC, 1995; IPPC, 2004a). The criteria of a quarantine pest is that it should either be absent from the PRA area or not widely distributed or under official control (Smith, 2004; IPPC, 1995). Where a pest is not officially controlled, or is widely spread it does not qualify to be a quarantine pest and phytosanitary measures should not be set for such a pest unless the plants are to be used for propagation purposes. Where it is to be used for propagation and control is needed, the pest is classified as a regulated non quarantine pest (IPPC, 2005). For this study, quarantine pests will be limited to those that do not occur in the Republic of South Africa.

(b) Introduction potential criteria

Throughout human history agricultural pests had a significant impact on the evolution and socio economic functions (Reichelderfer and Botrell, 1985). Introduction potential, also known as entry potential is dependent on the likelihood of a pest being associated with the controlled good (pathway) and the likelihood that the pest will establish in the area where it is introduced (IPPC, 1996). Introduction is mainly concerned with the probability of a pest passing through the import screening at port of entry (Hopper and Campbell, 1989). The number of people (tourists) passing through with the controlled goods, together with their movement to suitable environmental conditions for the pests in the pathway determine the risk of entry (IPPC, 1996).

Introduction potential has basically two critical levels; suitable conditions of travel and finding a suitable host and environmental conditions for reproduction. Therefore it is possible that pests can elude the border inspection and not find suitable hosts. Where countries are tempted to use prohibition to manage phytosanitary risks, it is highly likely that these measures will increase smuggling of that commodity (Koeman and Zadoks, 1999). Non declaration of controlled goods is viewed as a way of smuggling.

(c) ***Establishment criteria***

The number of pests that affects plants is much greater than those that affect animals and they can be present in an area for long periods before they are detected (Tanner, 1997). It is estimated that 45% of anthropods causing damage in SA are introduced (Myburgh, 1989). Many exotic pests were introduced unintentionally as hitchhikers on commodities (www.cast-science.org). A new species can exist in an area for years without being noticed as there might be a lag period where the exotic species is economically harmless and very rare. The lag between population growth and spread of pests ranges from 3 to 99 years after introduction (www.cast-science.org). Not all pests will become pests upon introduction as they might fail to adapt to ecological environment in terms of survival, reproduction and spread. This concept is known as transience (IPPC, 1999).

(d) Spread potential criteria

Once a pest has established it may spread to other areas (IPPC, 1998). The spread potential of a pest is critical for the evaluation of the economic importance of a pest. The rapid spread of *Bactrocera invadens* (Drew *et al.* 2005) in Africa signifies the importance of determination of the pest's economic importance (Mwatalala *et al.*, 2004). This fruit fly was only discovered in Sri Lanka after it was first found in Africa attacking a wide range of edible fruit (Drew *et al.*, 2005). The spread has been aggressive in tropical areas of Africa. Table 1.1 shows the chronology of the discovery of the *B. invadens* in Africa.

Table 1.1: Chronology of the discovery of *Bactrocera invadens* across Africa (Drew *et al.*, 2005)

Country	Date	Collection Information
Kenya	February 2003	Bred from fruit
Tanzania	December 2003	Bred from fruit
Sudan	May 2004	Methyl eugenol trapping
Benin	June 2004	Methyl eugenol trapping
Uganda	July 2004	Methyl eugenol trapping
Cameroon	August 2004	Bred from fruit
Togo	October 2004	Methyl eugenol trapping
Senegal	October 2004	Torula yeast trap
Ghana	January 2005	Methyl eugenol trapping
Nigeria	January 2005	Methyl eugenol trapping

(e) ***Economic importance criteria***

According to Pimentel *et al.* (2001), damages due to anthropods are estimated at US$44.6 billion in only six countries, including the United States US$ 15.9 billion, United Kingdom US$ 0.96 billion, Australia US$ 0.94 billion, South Africa US$ 1 billion, India US$ 16.8 billion and Brazil US$ 8.5 billion. Of the six countries listed, only the United States of America and Australia documented the environmental damage caused by these pests. The environmental damages were US$ 2.137 billion and US$ 0.228 billion respectively. The economic impact of pests on the environment is critical (IPPC, 2004a).

Pimentel *et al.* (2001) estimated the worldwide damage due to non native pests at US$137 billion. While economic evaluation of quarantine policy is important, it needs to be balanced against expected production gains, environmental losses and social welfare loss (Perelman, 1975).

Between 1982 and 1983 US$100 million was spent in California alone eradicating the Mediterranean fruit fly (www.cast-science.org)). In this attempt, the state had to pay US$ 3.7 million to settle 14 000 claims due to the insecticide applied that damaged car paint due to spray drift during aerial application (www.cast-science.org). The presence of a non native pest (exotic pest) has economic risks such as loss of production, diminished quality and decreased flexibility in production/management decisions (www.cast-science.org).

Introduced species may have greater competitive ability than existing species and the economic effects may lead to either direct or indirect losses (IPPC, 2004a). Direct losses will be through loss of yield and indirect will be through the knock on effects (e.g. having international market access denied for the commodities). The presence of Karnal Bunt in southwestern parts of the USA has prevented the exports of wheat grain to non infested countries (www.cast-science.org). Although the direct losses through the pathogen are minimal, the indirect losses are undesirable. The presence of citrus canker in Florida (USA) led to a programme that resulted in 11.7 million plants being eradicated at a cost of US$ 160 million, while it cost Japan US$ 250 million to eradicate the Oriental fruit fly, *B. dorsalis* and the melon fruit fly, *B. cucurbitae* (www.cast-science.org).

2.3.3 Pest risk management

Decisions of phytosanitary nature must be only made on information available (Maynard *et al.*, 2004). Pest Risk Management is the decision making process of reducing the risk of introduction of a quarantine pest (IPPC, 1997). This stage deals with the generation, evaluation and comparison of phytosanitary management options (IPPC, 1997). Thereafter the option that will provide an ALOP will be chosen. Normally upon choice of an option, monitoring and evaluation of the system will be conducted during importation.

(a) *Risk management options*

Risk management options differ in their efficacy. Risk management options include: country freedom, area freedom and commodity pest freedom or treatment or integrated pest management systems or mitigation treatments (www.ippc.int). These measures may be used individually or in an integrated approach (Maynard *et al*., 2004; IPPC, 2002). It is preferred that mitigation treatment be conducted in the country of origin (Hedley, 1990).

The use of mitigation treatments is critical for the control of quarantine pests to an ALOP.

(b) *Efficacy and Impact of options*

The objective for pest risk management is to achieve an ALOP (www.wto.org). Pest risk management options will differ in their efficacy (IPPC, 2004; www.usda.gov). The importing country has to ensure that the choice of risk management options provides an ALOP. These measures will be broadly discussed under inspections and quarantine security.

(i) Inspections

Inspection is a key element of pest risk management due to the economies of scale that it provides (Griffin, 2005). World trends indicate that countries with vigilant border control inspections are intercepting pests on a regular basis. Australia over the years intercepted an average of 600 pests per annum at their international borders (Maynard *et al*., 2004) while Japan, at Narita Airport intercepted 1 093 specimen of *B. dorsalis* complex were intercepted on fruit carried by passengers from Asian countries (Iwaizumi, 2004).

There is general acceptance that inspection is not adequate to ensure pest exclusion (Maynard *et al*., 2004). The difficulty in sourcing empirical estimates relating to the possibility of entry of a pest makes inspection a challenging task (James and Anderson, 1998). The efficacy of inspection is dependent on the intensity of inspection. Inspection intensity refers to the proportion of consignments of a given commodity or from a given origin that may be inspected (IPPC, 2005b). Factors to consider in deciding inspection intensity include:

- the end-use of the commodity
- the degree to which the commodity is a pathway for pests
- mobility of pests
- results of previous inspections (IPPC, 2005b)

(ii) Quarantine security

Quarantine security is the level of confidence that a quarantine treatment will disinfest quarantine pests from host commodities so the pest cannot become established in any geographical area where it does not exist (Fletcher, 1989). Quarantine is inherently

conservative from the view point of taking risks and better tools to manage risk and of determining an ALOP need to be developed (Cannon; 1998).
The main determinants of a treatment are effectiveness, efficiency and the product quality retention (Moy and Wong, 2002). Retention of the quality by the products relates to the marketability of the products after the treatment (Neven and Drake, 2000; Moy and Wong, 1996; Fletcher, 1989).

The main criterion for defining risk for anthropods is the probability of the survival of a mating pair in a shipment of fresh fruit (USDA, 1990). The quarantine security measurement for anthropods is Probit 9 which is the standard concept, based on not more than three survivors out of a treated population of 100 000 pests, giving a mortality rate of 99.997% (Baker, 1939). This level of quarantine security is based on a statistical probability that will ensure 95% confidence level on the efficacy of treatment. Currently there are variations to the standard Probit 9. Aegerter and Folwell (2000) treated a population of 1 million pests with 32 survivors. Couey and Chew (1986) treated a population of 93 600 pests with no survivors while Fletcher, (1989) treated a population of 30 000 targeted species with no survivors.

Probit 9 has come under scrutiny because of its inability to take the actual infestation levels of the host by the target quarantine pest at harvest into account (Fletcher1989). In order to counter actual infestation levels, some countries like New Zealand require the infestation level to be < 1 % before a recommended mitigation treatment can be conducted; this concept is known a Maximum Pest Limit (MPL (Harte *et al.*, 1992).

Baker *et al.* (1990) determined that the arrival of no more than three live larvae per geographical location per day was an adequate MPL to guard against the establishment of fruit fly on imported fruit.

CHAPTER 3

PEST RISK INITIATION

3.1 INTRODUCTION

Pest Risk Initiation is the first step in PRA (IPPC, 2004a). It deals with botanically identifying the commodity that is to be assessed and determining the parts of the plant that form part of the commodity (www.ippc.int). The commodities imported as hand luggage at O.R. Tambo International Airport were unknown and the detection of these commodities would assist in assessing the associated quarantine pests. The detection and quantification of commodities imported in hand luggage would assist in conducting risk assessment.

3.2 MATERIALS AND METHOD

The surveillance of targeted flights was done from 1st May 2002 to 30th April 2003. Midweek flights from India, Cameroon and Kenya were targeted (Annexure 1). The flights from Kenya that were targeted were KQ 460 and SA 183 and the surveillance done was on 48 and 40 flights respectively. Flight SA 277 from India was targeted and surveillance was conducted on 35 flights. Flight UY 808 from Cameroon was targeted and surveillance was conducted on 32 flights. In total, surveillance was conducted on 155 flights. Suspect passenger hand luggage was searched for plants and plant products. The detained plants and plant products were then inspected for quarantine pests. The fruit were dissected with an inspection knife for detection of internal feeders.

3.3 RESULTS

The monthly statistics for the period of study are summarized in Table 3.1.

Table 3.1: Plant products intercepted from hand luggage of passengers on flights from Cameroon, India and Kenya during May 2002 to April 2003

Months	Plant products and mass (kg) per country of origin		
	Cameroon	**India**	**Kenya**
May 2002	Plantains – 28	Mangoes – 54	Pineapples – 60 Mangoes -15 Pumpkins - 24
June 2002	**Plantains – 36 Yams - 40 Cassava leaves – 45**	**Mangoes – 35**	**Pineapples – 29 Mangoes - 24**
July 2002	Plantains – 42 Yams - 34 Cassava leaves – 19	Mangoes – 45	Pineapples – 43 Okra – 32
August 2002	**Yams – 43**	**0**	**Tanduri - 13 Okra – 10**
September 2002	Plantains – 46 Yams – 54	Citrus (lemons) – 37 Dates – 38	Ginger – 6 Garlic - 10 Okra – 22
October 2002	**Plantains – 64 Yams – 43**	**Citrus – 45 Dates – 32**	**Okra – 13**
November 2002	**Plantains – 45 Yams – 35**	**Dates – 39**	**Mangoes – 22**
December 2002	Yams – 50	0	Mangoes – 25
January 2003	**Yams – 32**	**0**	**Mangoes – 20**
February 2003	Yams – 43	Mangoes – 24	Pineapples – 37
March 2003	**Plantains – 35 Yams – 32**	**Mangoes – 35**	**Pineapples – 24**
April 2003	Plantains – 44 Yams – 38	Mangoes – 43	Pineapples 25 Okra – 8

3.2.1 Cameroon

The regulated articles intercepted the most were plantain fruit (*Musa paradisiaca*) and yam tubers (*Dioscorea batatas*). The other interception was of cassava leaves (*Manihot esculenta*). A total of 340 kg of plantains were intercepted over the survey period. Yam tubers intercepted amounted to 444 kg and 64 kg of cassava leaves were also intercepted. The interception of plantains was from May to November 2002, with no interception afterwards except for March and April 2003. The interception of yams was all through the duration of the study except in May 2002. In most instances, passengers would carry two to three yam tubers.

3.2.2 India

The interceptions from India were mainly mangoes from May to July 2002 and February to April 2003. In total 236 kg of mango fruit was intercepted. The fruit were mostly from commercial areas as they were packaged in commercial cartons averaging 10 kg. Lemon fruit (*Citrus limon*) were intercepted in September and December 2002. A total of 109 kg fresh dates (*Phoenix dactylifera* L.) were intercepted during the months of September to November 2002.

3.2.3 Kenya

The regulated articles that were detained mostly were pineapples (*Ananas comosus*) and mangoes (*Mangifera indica* L.) The pineapples intercepted were intercepted in May to July 2002 with further interceptions in February to April 2003. In total 218 kg of pineapple fruit were intercepted. A total of 106 kg mangoes were intercepted mainly during May and June 2002 and November 2002 to January 2003. The other interceptions were of okra (*Abelmoschus esculentus*), pumpkin gourds (*Cucurbita maxima* Duchesne ex Lam), tanduri and garlic gloves (*Allium sativum*).

3.3 DISCUSSION

The products intercepted were from tourists who indicated that they were not aware of South African phytosanitary import requirements. Other countries are experiencing the same challenge of uninformed travellers. Australia, with a good quarantine control had the same challenge of travellers who were unfamiliar with the quarantine regime (Stanton, 2004). The Agricultural Pests Act, (1983) provides the enabling legislative framework to prevent the entry of non-compliant consignments into South Africa.

The intended use for the intercepted goods was for consumption. The products were either for the passenger's personal consumption or for next of kin or friends. The quantities intercepted from flights from the three countries were high. Most of the products that were intercepted in large quantities, i.e. yams and plantains from Cameroon, mangoes and lemons from India and mangoes and pineapples from Kenya are in abundance in the countries of origin.

Based on the interception of the plant products from Cameroon, Kenya and India, these countries can be profiled for the likelihood of plants and plant products that may be carried as hand luggage. This area of study needs to be undertaken for extended periods for reliability. The next level is to determine quarantine pests that may be associated with these plant products.

In the past where there was little or no information on the pests associated with the plant products, prohibition was adopted as a phytosanitary measure. Prohibition or any other phytosanitary measure has to be based on scientific justification. Scientific justification is through identification of the probability of plants and plant products serving as a pathway for quarantine pests.

CHAPTER 4

PEST RISK ASSESSMENT

4.1 INTRODUCTION

The intercepted plant products from passenger luggage may serve as pathways for pests. The intercepted plant products were subjected to the next stage of PRA, pest risk assessment, to identify which pests are associated wit the intercepted plant products.

4.2 MATERIALS AND METHODS

The pest risk assessment was conducted using the 2003 Crop Pest Compendium (CPC) (www.cabicompendium.org). The CPC derives individual pest's records from positive identifications from peer-reviewed journals (Pasiecznik *et al.*, 2005). The CPC is edited by the Commonwealth Agricultural Bureau International (CABI). The pest risk assessment determines whether the intercepted plant products serve as a pathway for quarantine pests. The plant products that were intercepted were logged into the CPC interactive CD ROM and the CPC generated a list of quarantine and non quarantine pests that are associated with these products. Non quarantine pests were not considered as they do not require phytosanitary action.

4.3 RESULTS AND DISCUSSION

The CPC generated the following quarantine pests as associated with the intercepted plant products:

4.3.1 Pest Risk Assessment for Cameroon

Cassava leaves from Cameroon

(a) *Insects*

Araecerus fasciculatus (areca nut weevil)
Helopeltis bergrothi (cacao-mosquito)
Maconellicoccus hirsutus (pink hibiscus mealybug)
Metamasius hemipterus (West Indian cane weevil)
Phenacoccus madeirensis (cassava mealybug)
Pinnaspis strachani (lesser snow scale)
Pseudotheraptus devastans
Zonocerus variegatus (variegated grasshopper)

(b) *Mite*

Mononychellus tanajoa (cassava mite)

(c) *Fungi*

Cercospora caribaea (white leaf spot of cassava)
Mycosphaerella henningsii (brown leaf spot of cassava)
Phytophthora palmivora (black pod rot of cocoa)

(d) *Weeds*

Mimosa invisa (giant sensitive plant)
Solanum torvum (turkey berry)
Synedrella nodiflora (Cinderella weed (Australia))

Plantains from Cameroon

(a) *Insects*

Maconellicoccus hirsutus (pink hibiscus mealybug)
Pinnaspis strachani (lesser snow scale)

(b) *Weed*

Paspalum conjugatum (sour paspalum)

Yams tubers from Cameroon

No pests requiring phytosanitary action

4.3.2 Pest Risk Assessment for India

Fresh date fruit from India

(a) *Insects*

Bactrocera zonata (Saunders) (guava fruit fly)
Carpophilus humeralis (beetle, pineapple)
Maconellicoccus hirsutus (pink hibiscus mealybug)
Parlatoria blanchardi (Parlatoria date scale)
Rhynchophorus ferrugineus (Asiatic palm weevil)

(b) *Fungi*

Aspergillus fumigatus
Mycosphaerella tassiana (rot of pepper fruit)

(c) *Weed*

Asphodelus tenuifolius (onionweed)

Lemon fruit from India

(a) *Insects*

Adoretus versutus (Fijian cane root grub)
Aonidiella citrina (yellow scale)
Bactrocera carambolae (Drew and Hancock); (carambola fruit fly)
Bactrocera dorsalis species complex (Hendel); (Oriental fruit fly species complex)
Bactrocera minax (Chinese citrus fly)
Dialeurodes citri (citrus whitefly)
Diaphorina citri (Asian citrus psyllid)

Eudocima fullonia (fruit-piercing moth)
Pinnaspis strachani (lesser snow scale)
Psorosticha zizyphi (citrus leafroller)

(b) *Fungi*

Geotrichum candidum (sour rot: Citrus spp.)
Hypocrea rufa (fruit rot: Citrus spp.)
Septoria citri (septoria spot)

(c) *Bacterium*

Xanthomonas axonopodis pv. citri (citrus bacterial canker)

(d) *Virus*

Citrus yellow mosaic virus

(e) *Weed*

Commelina diffusa (spreading dayflower**)**

<u>Mango fruit from India</u>

(a) *Insects*

Acanthocoris scabrator (coreid bug)
Acrocercops syngramma (cashew leafminer)
Aleurodicus dispersus (spiralling whitefly)
Aleurothrixus floccosus (woolly whitefly)
Amritodus atkinsoni (mango leafhopper)
Anoplolepis longipes (crazy ant)
Apsylla cistellata (mango shoot psyllid)
Attacus atlas (atlas moth)
Bactrocera carambolae (carambola fruit fly)
Bactrocera caryae (Kapoor)
Bactrocera cucurbitae (Colliquet); (melon fly)
Bactrocera dorsalis (Hendel); (Oriental fruit fly)
Bactrocera dorsalis species complex (Oriental fruit fly species complex)
Bactrocera zonata (Saunders) ; (guava fruit fly)
Batocera rubus (lateral-banded mango longhorn)
Batocera rufomaculata (mango stem-borer)
Biston suppressaria (tea looper)
Cantheconidea furcellata

Ceroplastes ceriferus (Indian wax scale)
Chalcocelides castaneipars
Chlumetia transversa (mango shoot borer)
Cricula trifenestrata (tea flush worm)
Cryptoblabes gnidiella (christmasberry webworm)
Dasychira mendosa
Deanolis albizonalis (mango seed borer)
Deporaus marginatus (mango funnel-rolling leaf weevil)
Drosicha stebbingi (giant mealybug)
Erosomyia mangiferae (mango blossom midge)
Eudocima fullonia (fruit-piercing moth)
Homona coffearia (coffee tortrix)
Hypomeces squamosus (gold-dust beetle)
Icerya aegyptiaca (breadfruit mealybug)
Idioscopus clypealis (mango leafhopper)
Idioscopus nagpurensis (mango leafhopper)
Idioscopus niveosparsus (brown mango leafhopper)
Indarbela quadrinotata (bark borer)
Kerria lacca (lac, insect)
Leptocorisa acuta (rice seed bug)
Maconellicoccus hirsutus (pink hibiscus mealybug)
Megalurothrips distalis
Melanitis leda ismene (rice butterfly)
Microtermes obesi
Odontotermes wallonensis
Orgyia postica (cocoa tussock moth)
Orthaga euadrusalis
Orthaga exvinacea
Parasa lepida (nettle caterpillar)
Penicillaria jocosatrix (large mango tip borer)
Perissopneumon ferox
Pinnaspis strachani (lesser snow scale)
Planococcus lilacinus (cacao mealybug)
Planococcus minor (passionvine, mealybug)
Plocaederus pedestris
Rastrococcus iceryoides (downey snow line mealy bug)
Rastrococcus invadens (mango mealybug)
Retithrips syriacus (black vine thrips)
Rhipiphorothrips cruentatus (grapevine thrips)
Rhynchaenus mangiferae
Scirpophaga excerptalis (sugarcane top borer)
Sophonia rufofascia (two-spotted leafhopper)
Stauropus alternus (lobster caterpillar)
Sternochetus frigidus (mango flesh weevil)
Thrips hawaiiensis (flower thrips)
Thrips palmi (melon thrips)

Tirathaba mundella (oil palm bunch moth)
Xyleborus perforans (island pinhole borer)
Xyleborus similis
Xylosandrus crassiusculus (Asian ambrosia beetle)
Xylosandrus discolor

(b) ***Mites***

Aceria mangiferae (mango bud mite)
Cisaberoptus kenyae

(c) ***Fungi***

Corticium koleroga (thread blight)
Elsinoë mangiferae (mango scab)
Fusarium
Mycosphaerella tassiana (rot of pepper fruit)
Nectria rigidiuscula (cushion gall disease)
Oidium mangiferae (powdery mildew of mango)
Pestalotiopsis mangiferae (brown spot: mango)
Phytophthora heveae (brazil nut leaf blight)
Rhizopus arrhizus (barn rot: tobacco)
Setosphaeria rostrata (leaf spot of grasses)

(d) ***Bacterium***

Erwinia carotovora

(e) ***Weeds***

Axonopus compressus (carpet grass)
Kyllinga brevifolia (green kyllinga)

4.3.3 Pest Risk Assessment for Kenya

<u>Garlic from Kenya</u>

(a) ***Insect***

Araecerus fasciculatus (areca nut weevil)

(b) ***Mite***

Tyrophagus putrescentiae (cereal mite)

Ginger from Kenya

(a) *Insect*

Pinnaspis strachani (lesser snow scale)

Mango fruit from Kenya

(a) *Insects*

Aleurothrixus floccosus (woolly whitefly)
Bactrocera cucurbitae (melon fly)
Eudocima fullonia (fruit-piercing moth)
Helopeltis schoutedeni (cacao-mosquito)
Icerya aegyptiaca (breadfruit mealybug)
Maconellicoccus hirsutus (pink hibiscus mealybug)
Melanitis leda ismene (rice butterfly)
Pinnaspis strachani (lesser snow scale)
Planococcus lilacinus (cacao mealybug)
Rastrococcus iceryoides (downey snow line mealy bug)
Selenaspidus articulatus (West Indian red scale)
Xyleborus perforans (island pinhole borer)
Xyleborus similis
Xylosandrus crassiusculus (Asian ambrosia beetle)
Zonocerus variegatus (variegated grasshopper)

(b) *Fungus*

Elsinoë mangiferae (mango scab)

(c) *Weed*

Kyllinga brevifolia (green kyllinga)

Pineapples from Kenya

(a) *Insects*

Carpophilus humeralis (beetle, pineapple)
Eudocima fullonia (fruit-piercing moth)
Melanitis leda ismene (rice butterfly)
Zonocerus variegatus (variegated grasshopper)

(b) *Mite*

Tyrophagus putrescentiae (cereal mite)

(c) *Fungus*

Curvularia (black grain)

(d) *Weeds*

Commelina diffusa (spreading dayflower)
Emilia sonchifolia (red tasselflower)
Fimbristylis dichotoma (tall fringe rush)
Leptochloa chinensis (Chinese sprangletop)
Saccharum spontaneum (wild sugarcane)
Sida acuta (prickly sida)
Synedrella nodiflora (Cinderella weed (Australia)

Okra

(a) *Insects*

Anomis flava (cotton semi-looper)
*Diabolocatantops axillaris (*devil grasshopper)
Maconellicoccus hirsutus (pink hibiscus mealybug)
Pectinophora gossypiella (pink bollworm)

Pumpkins from Kenya

(a) *Insects*

Bactrocera cucurbitae (melon fly)
Pinnaspis strachani (lesser snow scale)

(b) *Bacterium*

Pseudomonas viridiflava (bacterial leaf blight of tomato (USA))

4.3.4 Commodities (pathways) from Cameroon

Based on the intercepted cassava leaves, plantains and yams, the pest risk assessment identified quarantine pests that may require phytosanitary action. The imported cassava leaves were always finely shredded and packed in plastic bags. This type of processing will most likely exclude the quarantine insect pests listed.

Plantains can serve as a pathway for three quarantine pests, *Maconellicoccus hirsutus, Pinnaspis strachani* and *Paspalum conjugatum.* Of the three pests, only *M. hirsutus* was observed on the plantain fruit, the others were observed on the plantain crop (www.cabi.compendium.org).

The CPC 2003 indicated that there were no quarantine pests for yams. But in 2003, yams that were imported into the Republic of South Africa on a commercial basis from Cameroon were laboratory tested and were found to be infested with *Scutellonema bradys* (yam dry rot nematode), a nematode for which the CPC lists yams, together with white yam (*Dioscorea alata*), air-potato (*D. bulbifera*), Asiatic yam (*D. esculenta*) and cow pea (*Vigna unguiculata*) as major hosts. The nematode is widely distributed in Cameroon (www.cabicompendium.org).The inclusion of *S. bradys* as a quarantine pest for South Africa is critical. The inclusion will assist in determining phytosanitary risk management actions.

4.3.5 Commodities (pathways) from India

The pest risk assessment results indicate that dates imported from India may be associated with five quarantine insects of which only two are known to be associated with the date fruit. Of the two one is an internal feeder, *Bactrocera zonata* and the other an external feeder, *Maconellicoccus hirsutus*. The fungi and the weed listed were also only known to be associated with the host crop and not the fruit. Therefore only *B. zonata* and *M. hirsutus* may require phytosanitary action.

The lemon fruit has sixteen quarantine pests listed. Of all these pests, only 4 are known to be associated with the fruit. These pests are *Bactrocera carambolae*, *B. minax*, *Xanthomonas axonopodis* pv. *citri* and Citrus yellow mosaic virus. The CPC omitted *B. dorsalis* species complex from the listing. Lemons are classified as a major host of this complex of fruit flies ((Drew and Hancock, 1994). The *B. dorsalis* complex needs to be documented by the CPC as a quarantine pest for lemons.

The mango fruit had eighty four quarantine pests listed and the pests recorded by the CPC (2003) to be associated with the fruit are *Bactrocera carambolae*, *B. cucurbitae*, *B. dorsalis*, *B. zonata* (fruit flies), *Erosomyia mangiferae*, *Maconellicoccus hirsutus*, *Elsinoë mangiferae*, *Nectria rigidiuscula* and *Phytophthora heveae*. Only nine of the eighty four were recorded to be infesting or infecting mango fruit by the CPC.
Based on the recordings on the fruit and the pest listing of quarantine pests, it is debatable whether a PRA is a true scientific tool as phytosanitary measures are based on available

information. The available information has not demonstrated that some of the listed pests were observed on mango fruit. Drew and Hancock (1994) list mango fruit as major hosts of *B. caryae* and *B. dorsalis* complex species and these fruit flies are widely distributed in India but were omitted by the CPC. The CPC has to document *B. caryae* and *B. dorsalis* complex as quarantine pests.

4.3.6 Commodities from Kenya

The assessment on garlic gloves using the CPC (2003) listed one insect and one mite during the evaluation and both are not known to be associated with the garlic gloves. For the ginger, only one pest, *Pinnaspis strachani* was listed by the CPC.

The CPC (2003) listed 17 quarantine pests of which 4 are recorded to be associated with the pathway mango fruit from Kenya. These are *Bactrocera cucurbitae*, *Helopeltis schoutedeni, Maconellicoccus hirsutus* and *Elsinoë mangiferae*. Since *B. invadens* is present in Kenya, this fruit fly needs to be documented by the CPC database as a pest on mango fruit from Kenya.

The CPC (2003) lists four 4 insect pests, a mite, a fungus and seven weed pests as quarantine pests of pineapple fruit from Kenya. Of the quarantine pests listed, none was recorded on by the CPC on pineapple fruit. For okra, the CPC (2003) had four insects to be listed of which only *Maconellicoccus hirsutus* was recorded on okra fruit. The CPC

(2003) listed three quarantine pests for pumpkins but only *Bactrocera cucurbitae* and *Pseudomonas viridiflava* were reported on pumpkin gourds.

CHAPTER 5

QUANTITATIVE PEST RISK ASSESSMENT OF BACTROCERA FRUIT FLIES

5.1 INTRODUCTION

The CPC (2003) on the plant products from Chapter 4 listed numerous quarantine pests for the plant and plant products that were intercepted at O.R. Tambo International Airport. Of all quarantine pests, none has the economic importance of fruit flies. Hence for the pest risk management only the *Bactrocera* fruit flies were considered.

The main *Bactrocera* species that were regarded as major risks were *Bactrocera carambolae* (carambola fruit fly); *B. caryae; B. cucurbitae* (melon fly); *B. dorsalis* (Oriental fruit fly); *B. dorsalis* species complex (Oriental fruit fly species complex); *B. invadens* and *B. zonata* (guava fruit fly). In order to fully understand the process of pest risk assessment, the identified species were subjected to a quantitative pest risk assessment.

Globally most mangoes are grown in fruit fly infested areas (Peńa *et al*., 1998). Fruit flies cause both direct and indirect economic losses. Indirect losses are mainly through loss of revenue where phytosanitary import requirements are imposed by importing countries and direct losses are mainly due to reduction in yield and increased pest control costs (IPPC, 2004).

According to White and Elson – Harris (1992) there are 48 species of fruit flies that are of economic importance, of which the *Bactrocera* genus represents 30 species. The Florida Department of Agriculture and Consumer Services (2003) lists 68 species of the *B. dorsalis* complex of fruit flies while Drew and Hancock (1994) recorded 58 species. These differences in the number of species already indicate uncertainty amongst scientists about the number of species as new species are regularly identified. Of the 58 species listed by Drew and Hancock (1994), eight species were found to be of economic importance, *B. dorsalis, B. dorsalis complex*, *B. papayae, B. carambolae*, *B. phillipinensis*, *B. occipitalis*, *B. caryeae* and *B. kandiensis*, while Fletcher (1989) considers the major species being *B. tryoni* Frogatt, *B. zonata* Saunders and *B. dorsalis* Hendel. As the species differ, treatments for their control may also differ. The *B. dorsalis* complex has wide distribution in Asia, Australia, Pacific Islands and lately Africa (Mwatalala *et al*., 2004).

Fruit flies are difficult to identify and computer aided identification systems are being developed to assist in the identification (Nai-zhong and Zuo-rui, 2003). The complexity associated with the identification were also experienced with the identification of *B. invadens* as it was only identified as occurring in Sri Lanka long after detection in Africa (Mwatalala, 2004).

5.2 MATERIALS AND METHODS

Pest risk assessment can either be done on a qualitative basis or on a quantitative basis (IPPC, 2004). A quantitative pest risk assessment for fruit flies is conducted using the EPPO system (McLeod and Baker, 2003). The system assigns scores to the questions posed with a ranking of 1 to 9. The system simplifies the risk assessment and also gives standardized answers towards the pest risk assessment questions of:

(1) Geographical and regulatory criteria,
(2) Introduction potential,
(3) Establishment potential,
(4) Spread potential and
(5) Economic importance criteria.

For this study eight questions were selected dealing with introduction and establishment potential. These questions, derived from Macleod and Baker (2003), are accompanied by guidance scoring procedures on score allocation. The CPC (2003) was used as reference for *Bactrocera* fruit flies' hosts.

5.2.1 How many pathways can a pest be carried on?

The determination of the pathways is based on the number of host plants. The EPPO system gives a suggestion on how to allocate scores. Based on Macleod and Baker (2003) the scores are given Table 5.1.

Table 5.1: Scoring suggestions for number of pathways (McLeod and Baker, 2003)

Score	Description of pathways
1	1
2	2 - 10
3	11 - 100
4	101 - 250
5	251 - 500
6	501 - 1000
7	1001 - 5000
8	5001 - 10000
9	10000 +

Based on the scoring system, and based on the number of commodities imported from Kenya and India that may harbour the *Bactrocera* fruit flies, the allocated score will be the same for all *Bactrocera* fruit flies. The commodities which may be associated with these flies from India and Kenya are less than ten. Since the detained products at O.R. Tambo International Airport are not the only exclusive hosts for the *Bactrocera* fruit flies, the score for the *Bactrocera* fruit flies will be based on their host range.

The score for all *Bactrocera* fruit flies is 2

(a) ***The host range for Bactrocera carambolae (carambola fruit fly*):**

The major hosts listed are:

Annona muricata (soursop), Artcarpus integer, Averrhoa carambola (carambola), Carica papaya (papaw), Citrofortunella mitis , Citrus aurantiifolia (lime), Citrus limon (lemon), Fortunella margarita (oval kumquat), Garcinia mangostana (mngosteen), Mimusops elengi (Asian bulletwood), *Persea americana (avocado), Pouteria campechiana, Psidium cattleianum (strawberry guava), Punica granatum (pomegranate), Rhizophora, Rollinia pulchrinervis, Syzygium aqueum (water apple), Syzygium jambos (rose apple), Thevetia peruviana.*

The minor hosts are:

Anacardium occidentale (cashew nuts), *Arenga pinnata* (sugar palm),*Artocarpus altilis*(breadfruit),*Artocarpus heterophyllus* (jackfruit),*Averrhoa bilimbi, Capsicum annuum* (bell pepper)*, Chrysophyllum cainito* (caimito),*Citrus reticulate*(mandarin), *Citrus sinensis*(navel orange), *Citrus X paradisi* (grapefruit), *Eugenia uniflora*(brazil cherry), *Lycopersicon esculentum* (tomato), *Malpighia glaba* (acerola), *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Psidium guajava* (common guava), *Syzygium malaccense* (malay-apple), *Syzygium samarangense* (Malay apple), *Terminalia catappa* (beach almond), *Ziziphus jujube* (common jujube).

The score for *Bactrocera carambolae* is 3

(b*) The host range for Bactrocera caryae:*

The major hosts listed are:

Aegle marmelos (bael fruit), Citrus maxima (pummelo), Citrus reticulate (mandarin), Malpighia glabra (acerola),Mangifera indica (mango), Pouteria sapota, Psidium guajava (common guava).

The score for *Bactrocera caryae* is 2

(c) The host range for Bactrocera cucurbitae (melon fly):

The major hosts are:

Cucumis melo (melon), *Cucurbita maxima* (banana squash), *Cucurbita pepo* (ornamental gourd), *Trichosanthes cucumerina var. anguinea* (snakegourd).

The minor hosts are:

Abelmoschus moschatus, Artocarpus heterophyllus (jackfruit), *Benincasa hispida* (wax gourd), *Carica papaya* (papaw), *Citrullus colocynthis* (colocynth), *Citrullus lanatus* (watermelon), *Citrus maxima* (pummelo), *Citrus sinensis* (navel orange), *Cucumis auguria* (gerkin), *Cucumis sativus* (cucumber), *Cucurbita moschata* (pumpkin), *Cydonia oblonga* (quince), *Cyphomandra betacea* (tree tomato), *Ficus carica* (common fig), *Lagenaria siceraria* (bottle gourd), *Luffa acutangula* (angled luffa), *Luffa aegyptiaca* (loofah), *Lycopersicon esculentum* (tomato), *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Momordica balsamina* (common balsamapple), *Momordica charantia* (balsam apple), *Passiflora edulis* (passionfruit), *Persea Americana* (avocado), *Phaseolus vulgaris* (common bean), *Prunus persica* (peach), *Psidium guajava* (common guava), *Sechium edule, Sesbania grandiflora* (agati), *Syzygium samarangense* (malay apple), *Trichosanthes cucumerina, Vigna unguiculata* (cowpea), *Ziziphus jujube* (common jujube).

The wild hosts are:

Citrus hystrix and Cucurbitaceae (cucurbits)

The score for *Bactrocera cucurbitae* is 3

(d) The host range for Bactrocera dorsalis (Oriental fruit fly):

The major hosts are:

Aegle marmelos (bael fruit), *Anacardium occidentale* (cashew nut), *Annona reticulate* (bullock's heart),*Annona squamosa* (sugarapple), *Areca catechu* (betelnut palm), *Artocarpus altilis* (breadfruit), *Artocarpus heterophyllus* (jackfruit), *Averrhoa carambola* (carambola), *Capsicum annuum* (bell pepper), *Carica papaya*(papaw), *Chrysophyllum cainito* (caimito), *Citrus, Citrus aurantiifolia* (lime), *Citrus maxima*(pummelo), *Citrus reticulate* (mandarin), *Coffea arabica* (Arabica coffee), *Cucumis melo* (melon), *Cucumis sativus* (cucumber), *Dimocarpus longan* (longan tree), *Diospyros kaki* (oriental persimmon), *Ficus racemosa* (cluster tree), *Flacourtia indica, Malpighia glabra* (acerola), *Malus pumila* (apple), *Mangifera foetida* (bachang), *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Mimusops* elengi (Asian bulletwood), *Momordica charantia* (balsam apple), *Muntingia calabura* (Jamaica cherry), *Musa* (banana), *Nephelium lappaceum* (rambutan), *Persea Americana* (avocado), *Prunus armeniaca* (apricot), *Prunus avium* (sweet cherry), *Prunus cerasus* (sour cherry), *Prunus domestica* (plum), *Prunus mume* (Japanese apricot tree), *Prunus persica* (peach), *Psidium guajava* (common guava), *Punica granatum* (pomegranate), *Pyrus communis* (European pear), *Spondias purpurea, Syzygium aqueum* (water apple), *Syzygium aromaticum* (clove), *Syzygium cumini* (black olum tree), *Syzygium jambos* (rose apple), *Syzygium malaccense* (malay-apple), *Syzygium samarangense* (malay apple), *Terminalia catappa* (beach almond), *Ziziphus jujuba* (common jujube), *Ziziphus mauritiana* (jujube).

The minor host is:

Litchi chinensis (litchi)

The score for *Bactrocera dorsalis* is 3

(e) The host for Bactrocera dorsalis species complex (Oriental fruit fly species complex):

The major hosts are:

Annona muricata (soursop), *Annona reticulate* (bullock's heart), *Annona squamosa* (sugarapple), *Artocarpus altilis* (breadfruit), *Averrhoa carambola* (carambola), *Blighia sapida* (Akee apple), *Capsicum annuum* (bell pepper), *Carica papaya* (papaw), *Citrullus lanatus* (watermelon), *Citrus limon* (lemon), *Citrus maxima* (pummelo), *Citrus reticulate* (mandarin), *Citrus sinensis* (navel orange), *Citrus, Coffea* (coffee), *Diospyros lotus* (Date plum tree), *Eriobotrya japonica* (loquat), *Eugenia uniflora* (brazil cherry), *Feijoa sellowiana* (Feijoa fruit), *Ficus, Lycopersicon esculentum* (tomato), *Malpighia glabra* (acerola), *Malus pumila* (apple), *Mangifera indica* (mango), *Muntingia calabura* (Jamaica cherry), *Musa sapentium* (banana), *Musa x paradisiacal* (plantain), *Persea americana* (avocado), *Physalis peruviana* (cape gooseberry), *Prunus armeniaca* (apricot), *Prunus domestica* (plum), *Prunus persica* (peach), *Psidium guajava* (common guava), *Psidium longipes* (strawberry guava), *Pyrus communis* (European pear), *Solanum seaforthianum, Spondias purpurea***,** *Syzygium aqueum* (water apple), *Syzygium jambos* (rose apple), *Syzygium malaccense* (malay-apple), *Syzygium samarangense* (malay apple), *Terminalia catappa* (beach almond).

The minor hosts are:

Anacardium occidentale (cashew nut), *Arenga pinnata* (sugar palm), *Artocarpus heterophyllus* (jackfruit), *Averrhoa bilimbi, Chrysophyllum cainito* (caimito), *Citrus x paradisi* (grapefruit), *Manilkara zapota* (sapodilla), *Momordica charantia* (balsam apple), *Nephelium lappaceum* (rambutan), *Passiflora edulis* (passionfruit), *Solanum torvum* (turkey berry), *Spondias cytherea* (ambarella), *Ziziphus jujube* (common jujube), *Ziziphus mauritiana* (jujube).

The score for *Bactrocera dorsalis* species complex is 3

According to Drew *et al.,* (2005) the major hosts are:

Psidium guajava (guava), *Mangifera indica* (mango), *Citrus spp* (citrus fruit), *Carica papaya* (papaya), Lycopersicon esculentum (tomato)

According to Drew *et al.,* (2005) the wild host is:

Strychnos spp.

The score for *Bactrocera invadens* is 2

(f) The host range of Bactrocera zonata (guava fruit fly):

The major hosts are:

Mangifera indica (mango), *Prunus persica* (peach), *Psidium guajava* (common guava).

The minor hosts are:

Aegle marmelos (bael fruit), *Annona squamosa* (sugarapple), *Carica papaya* (papaw), *Citrus, Cydonia oblonga* (quince), *Ficus carica* (common fig), *Grewia asiatica* (phalsa), *Luffa, Malus pumila* (apple), *Momordica charantia* (balsam apple), *Phoenix dactylifera* (date-palm), *Punica granatum* (pomegranate), *Terminalia catappa* (beach almond).

The wild host is:
Careya arborea (slow match tree)

The score for *Bactrocera zonata* is 3

5.2.2 How large is the movement along the pathway?

The total weight of the consignments that came through is taken into consideration. The scoring according to McLeod and Baker, 2003 as demonstrated in Table 5.2 was applied.

Table 5.2: Scoring suggestions for movement along the pathway (McLeod and Baker, 2003)

Score	Description: weight of the commodity imported
1	< 1 tonne
2	1 – 10 t
3	11 – 100 t
4	101 – 1000 t
5	1001 – 10 000 t
6	10 001 – 50 000 t
7	50 001 – 75 000 t
8	75 001 – 100 000 t
9	100 000 t +

Based on the weight of the annual detentions for all respective flights, all the *Bactrocera* fruit flies will score the same as the detained potential pathways for fruit flies were less than 1 tonne.

The score for all *Bactrocera* fruit flies is 1

5.2.3 How widely is the commodity distributed within the PRA area?

A quarantine pest is defined as a pest of potential economic importance to the area endangered thereby and not yet present there and the *Bactrocera* fruit flies are absent in South Africa. The meaning of a quarantine pest is therefore interpreted to mean that the whole of South Africa will be an area considered to be at risk or endangered by the Bactrocera fruit flies. Although commercial production of the major host crops are limited to specific regions, some host plants are grown in home gardens all over South Africa all over South Africa. South Africa also has indigenous plants that may serve as new hosts of fruit flies if they enter and establish in South Africa.

The EPPO guidance for this procedure as outlined in Table 5.3, distinguishes between areas to ensure that the scores are allocated according to the endangered localities or areas.

Table 5.3: Scoring suggestions for distribution of the commodity (pathway) within the PRA area (McLeod and Baker, 2003)

Score	Description: how far is the commodity to be distributed	% of PRA area
1	One single location	Insignificant
2	Up to one field/one single location	Up to 0.001
3	Up to a single farm or single production site	Up to 0.01
4	Locally only within a sub national political district	Up to 1.0
5	Within a single sub national region	Up to 20.0
6	Within two sub national regions	Up to 33.0
7	With more than two regions but less than half of PRA area	Up to 50.0
8	Within half to 75% of PRA area	Up to 75.0
9	Across the entire PRA area	Up to 100.0

The score for all *Bactrocera* fruit flies is 9

5.2.4 How widely spread is the arrival time of the commodities

The commodities that were intercepted were well spread, but the interceptions showed seasonality as some of the fruit was intercepted only during specific times as discussed in Chapter 3. The frequency of the commodity arrival is linked to the number of pests that may be imported through the pathway. The EPPO scoring suggestion is captured in Table 5.4.

Table 5.4: Scoring suggestions for frequency of arrival of commodities (McLeod and Baker, 2003)

Score	Description: frequency of commodity import
1	Once a year or less
2	More than once a year but only during one month of the year
3	During 2 different months of the year
4	Up to 3 months of the year
5	Up to 4 months of the year
6	Up to 6 months of the year
7	Up to 8 months of the year
8	Up to 10 months of the year
9	Up to every month of the year

Based on the number of the commodity interceptions:

The score for all *Bactrocera* fruit flies is 9

5.2.5 How many host plant species are present in the PRA area?

The CPC database lists host plants of Bactrocera fruit flies' which grow in South Africa. This database excludes probable wild hosts as the pests are absent in the PRA area and therefore the suitability of potential wild hosts growing in South Africa is unknown. It must also be noted that the current host list may be incomplete as shown by the increasing number of hosts that were previously not recorded for *Bactrocera invadens* (Mwatalala *et al.*, 2004).

The EPPO scoring criteria used is shown in Table 5.5.

Table 5.5: Scoring suggestions for the number of host plant species present in the PRA area (McLeod and Baker, 2003)

Score	Description: number of host species present in the PRA area
1	One species
2	2, 3, 4 species
3	5 – 10 species
4	11 – 18 species
5	19 – 25 species
6	26 – 50 species
7	51 – 100 species
8	101 – 200 species
9	Over 200 species

The actual scoring based on the information on host plants as derived from the CPC are given in Table 5.6 based on the number of host plant species known to be grown in South Africa.

Table 5.6: Scores awarded for *Bactrocera* fruit flies based on the number of host plant species present in a PRA area

Bactrocera fruit fly species	Score
Bactrocera carambolae (carambola fruit fly)	4
Bactrocera caryae	2
Bactrocera cucurbitae (melon fly)	5
Bactrocera dorsalis (Oriental fruit fly)	5
Bactrocera dorsalis species complex (Oriental fruit fly species complex)	5
Bactrocera invadens	2
Bactrocera zonata (guava fruit fly)	3

5.2.6 How extensive are host plants in the PRA area?

The distribution of the host plants represents the basis for determining the establishment potential of pests. The EPPO scoring uses the criteria in Table 5.7 to determine the possibility of establishment. The possibility of establishment is a linkage between how far the commodity may be distributed and the availability of the host plants. The assumption is that the wider the spread of the host, the higher the potential that the pest will be provided with a food source during its incursion.

Table 5.7: Scoring suggestions for the distribution of the host plants in the PRA area (McLeod and Baker, 2003)

Score	Description: how extensive are the host plants in the PRA area?
1	One single location
2	Up to one field/one single location
3	Up to a single farm or single production site
4	Locally only within a sub national political district
5	Within a single sub national region
6	Within two sub national regions
7	With more than two regions but less than half of PRA area
8	Within half to 75% of PRA area
9	Across the entire PRA area

The host plants for the Bactrocera fruit flies were outlined in 5.3.1. The host plants growing in South Africa are spread across the commercial fruit growing areas of South Africa and home gardens all over South Africa. South Africa has a host of wild fruit that may serve a host for the *Bactrocera* fruit flies. The scores are reflected in Table 5.8.

Table 5.8: Scores of certain *Bactrocera* fruit flies based on the number of host plant species present in a PRA area

Bactrocera fruit fly species	Score
Bactrocera carambolae (carambola fruit fly)	9
Bactrocera caryae	9
Bactrocera cucurbitae (melon fly)	9
Bactrocera dorsalis (Oriental fruit fly)	9
Bactrocera dorsalis species complex (Oriental fruit fly species complex)	9
Bactrocera invadens	7
Bactrocera zonata (guava fruit fly)	9

5.2.7 How similar are the climatic conditions that would affect pest establishment in the PRA area and in the area of origin?

Climatic conditions in India and Kenya were compared with that prevailing in South Africa using the Kőppen climate classification map (Trewartha modification), which is widely used by geographers and plant ecologists (www.umwc.uwc.edu). The EPPO system recommends the Climex system. The Climex system was not used in this study due to cost implications. The scoring suggestion is given in Table 5.9.

Table 5.9: Scoring suggestions for climatic similarities that would affect pest establishment in the PRA area and in the area of origin (McLeod and Baker, 2003)

Score	Description: Climate match index from within the PRA area and the area of origin
1	0-5 climatic conditions are extremely different
2	6 - 17
3	18 – 29
4	30 – 41
5	42 – 53
6	54 – 65
7	66 - 77
8	78 - 79
9	90 – 100 (climatic conditions extremely identical)

Most parts of South Africa fall within the BSh classification, which is sub tropical with a cool dry season and such climatic conditions also exist in parts of India. This climatic classification is the only similarity between India and South Africa. Furthermore India has three distinct climate classifications Am and Af, which are humid and tropical and Aw which is monsoon climate. Climatic conditions in Kenya are different to South African conditions. Kenya also falls largely within the Af climatic conditions, which are similar to parts of Mozambique adjacent to the South African north eastern border. The threat for Southern Africa in terms of natural dispersal of *Bactrocera* fruit flies will more likely be Mozambique.

The scoring suggested score due to a match between India and South Africa:

The score for all *Bactrocera* fruit flies is 4

5.2.8 How often has the pest been introduced into new areas outside its original range?

The likelihood of establishment will also be linked to the spread of the pest from its original habitat. The biggest challenge in terms of the *Bactrocera* fruit flies is whether they are climate specific or adaptable to different climatic conditions. Most fruit flies are very adaptive to lower temperatures (Vargas *et al*., 2000; Vargas *et al*., 1997; Yang *et al*., 1994). The answer may lie with areas where they were previously introduced and established over the past years. The adaptability of the pest will be judged by its spread from its origin and Table 5.10 denotes the EPPO criteria used.

Table 5.10: Scoring suggestions for the number and locations of countries to which the pest has spread (McLeod and Baker, 2003)

Score	Description: number and locations of countries to which the pest has spread
1	Has never been introduced elsewhere
2	Has only spread within a single country outside its original range
3	Has been introduced to neighbouring countries in the same continent
4	Has been introduced to all countries in the same continent
5	Has been introduced to one other continent in the same hemisphere
6	Has been introduced to two or more continents in the same hemisphere
7	Has been introduced into at least one country in each continent
8	Has been introduced to a few countries in all continents
9	Has been introduced to several countries in all continents

Based on scoring suggestions the following scores were obtained as in Table 5.11.

Table 5.11: Scores based on the number and locations of countries to which certain *Bactrocera* fruit flies have spread

Bactrocera fruit fly species	Source	Score
Bactrocera carambolae (carambola fruit fly)	(EPPO, 2004; www.cabicompendium.org)	6
Bactrocera caryae	(White and Elson –Harris, 1994)	1
Bactrocera cucurbitae (melon fly)	(EPPO, 2004; www.cabicompendium.org)	6
Bactrocera dorsalis (Oriental fruit fly)	(EPPO, 2004; www.cabicompendium.org)	6
Bactrocera dorsalis species complex	(EPPO, 2004; www.cabicompendium.org)	6
Bactrocera invadens	(Drew *et al*., 2005)	6
Bactrocera zonata (guava fruit fly)	(EPPO, 2004; www.cabicompendium.org)	6

The EPPO criteria showed that except for *B. caryae*, all the other *Bactrocera* fruit flies were introduced to two or more continents, which are at times not in the same hemisphere. The EPPO criteria therefore fail to take into account the spread of pests to two or more continents not in the same hemisphere. This creates uncertainty on the scoring aspect.

B. dorsalis is widely spread in Asia and has been introduced to North America in Hawaii and to Oceania in Australia (EPPO, 2004; www.cabicompendium.org). *B. dorsalis* complex has also spread to other countries with 47 species recorded to have spread beyond their natural ranges (EPPO, 2004; www.cabicompendium.org, www.eppo.org). *B. carambolae* and *B. zonata* have also spread (EPPO, 2004; www.cabicompendium.org).

B. invadens has recently been detected in Africa and is spreading as already discussed ((Drew *et al*., 2005).

Based on the scoring that was done for the 8 questions, a summary of the scores was developed as reflected in Table 5.12.

Table 5.12: Summary of the scoring for the *Bactrocera* fruit flies

	B. carambola	*B. caryae*	*B. cucurbitae*	*B. dorsalis*	*B. dorsalis complex*	*B. invadens*	*B. zonata*
5.4.1	3	2	3	3	3	3	3
5.4.2	1	1	1	1	1	1	1
5.4.3	9	9	9	9	9	9	9
5.4.4	6	6	6	6	6	6	6
5.4.5	4	2	5	5	5	2	3
5.4.6	9	9	9	9	9	9	9
5.4.7	4	4	4	4	4	4	4
5.4.8	6	1	6	6	6	6	6
TOTAL	**42**	**34**	**43**	**43**	**43**	**40**	**41**

5.3 DISCUSSION

Quantitative pest risk assessment is more intense than qualitative risk assessment. Not all *Bactrocera* fruit flies will score the same for all criteria. Each species will have areas where it will score lower than the other species, depending on the critical area where the pest risk assessment question is posed.

All *Bactrocera* fruit flies scored low on the number of pathways that they may be carried on. This is due to the number of commodities that were detained at OR Tambo International Airport. Therefore there is a correlation between the number of commodities detained and the entry potential. But the contextualization of the score is that while the entry potential is based on the number of products detained, there is no linkage to the biology of the pest, in this case *Bactrocera* fruit flies. These fruit flies can lay up to 40 eggs in a batch as indicated by Fletcher (1989) and in terms of the Probit 9 (which will be discussed later); more than three survivors are deemed capable of initiating a new population.

Due to the absence of a tracking system to identify where the passengers (tourists) are destined to, the whole of the Republic of South Africa was deemed to be the PRA for this study. The arguments against the whole of the Republic of South Africa being a PRA would be that the climatic conditions, the flora and agro – ecosystems vastly differ within South Africa.

The commodities are imported on a seasonal basis as already discussed in Chapter 3. The score for all *Bactrocera* fruit flies was 6, based on the imports that were detained. The pest risk management applied in the growing areas where these commodities were grown is unknown and therefore the risk posed by these commodities is high.

The *Bactrocera invadens* case has proven that the host range of a pest cannot be ascertained where it is introduced as it might attack new hosts. South Africa has a wide range of indigenous plants which may be conducive for the establishment and spread of the *Bactrocera* fruit flies. For instance in India *B. dorsalis* is known to attack 140 plant species mainly cucurbits (Kapoor, 1996). All *Bactrocera* fruit flies were scored at maximum on the extent of host plant availability in South Africa. Hence an assumption can be made that provided that climatic conditions are suitable, the probability of these flies establishing in South Africa is extremely high.

The climatic mapping of the three countries was done using the Koppen climatic maps as already discussed. Global climate change scenarios are still not adept in predicting the effects it will have on pest introductions and invasions but it creates scenarios that can be used to formulate early warning systems (Simberloff, 2000). This shows that it is difficult using climatic mapping to predict establishment. Since fruit has been imported into South Africa from both Kenya and India previously the question can be asked why has there not been an establishment of the *Bactrocera* fruit flies? Hence the relevant follow up question would be identifying countries where these fruit flies had being previously introduced and how many times have these flies established outside their natural range?

Except for the *B. caryae*, all *Bactrocera* fruit flies had been introduced in other continents. This poses a threat to South Africa as the eradication programmes are very expensive. It is imperative that a stronger border control component be kept to identify and manage these risks of intentional and unintentional introduction of quarantine pests. It is accepted that due to South Africa sharing borders with other countries, some quarantine pests if introduced into other countries can migrate into South Africa. Hence having early warning systems is vital for South Africa.

Using quantitative analysis gives a clear picture of the risk posed by pests. It is evident from the scores that the *Bactrocera* fruit flies pose a serious threat to the South African fruit industry and the environment.

CHAPTER 6

PEST RISK MANAGEMENT

6.1 INTRODUCTION

Pest risk management is the final stage of the PRA, which is basically aimed at finding the most suitable option(s) for the control of quarantine pests to an ALOP. Solutions adopted towards potential pest problems should be location, pest and crop specific (Strand 2000).

The desired state in quarantine control is that a commodity sourced from an area free from quarantine pests. Alternatively consignments are to be free from quarantine pests. Failure to assure either of the two phytosanitary requirements may lead to other measures which may include mitigation treatments and other phytosanitary actions. This chapter evaluates phytosanitary measures that may be used against fruit flies with the aim of selecting the most suitable measure or a combination of measures. Most of the phytosanitary treatments are temperature based (Mangan and Hallman, 1999). The methods discussed are ionizing irradiation, heat treatment, methyl bromide treatment and cold treatment.

6.2 IONIZING IRRADIATION

Irradiation can be used for different purposes such as disinfestation, decontamination and sterilization (Moy and Wong, 2002). Irradiation for anthropod quarantine control is based on applying lower doses to render the pests infertile or to prevent the pests from developing into the next life stage, rather than killing the pest (Ignatowicz and Brzostek, 2002). In the case of fruit flies, it is used to prevent eggs from hatching or adults from reproducing (Moy and Wong 2002). Table 6.1 depicts the different radiation treatments. Irradiation for phytosanitary purposes in fresh fruit does not lead to acute mortality of pests and hence live insects can be present in irradiated consignments but these pests if treated at the recommended dosage rate will not give rise to offsprings (Ignatowicz and Brzostek, 2002).. Irradiation may be applied as a single treatment or in a combination with other treatments in controlling insects and limiting risk to an acceptable level (Ross and Engeljohn, 2000). Irradiation can replace methyl bromide fumigation in countries where the use of methyl bromide is banned (Marcotte, 1998).

The irradiation process involves the use of ionizing radiation to control insects (Aegerter and Folwell, 2000). The basic measurement of irradiation dose is grey (Gy), which is the amount of ionizing radiation absorbed by the material being irradiated in joules per kilogram of material (Hallman, 2000). Previously the absorbed irradiation dose was measured as rad which equaled 0.01 Gy. Ionizing irradiation in food has four sources, gamma irradiation which can either be cobalt 60, caesium 137, electron beam (beta particles) or X-rays (bremsstrahlung).

Commercial irradiation is done in premises having conveyor systems and materials pass through the system at a certain rate measured in time to achieve the required efficacy dosage, or alternatively a chamber is used to irradiate the material with a radioactive source taking time and dosage rate into cognizance (Hallman, 2000).

Table 6.1 Suggested objectives of radiation quarantine treatments based on most advanced growth stage found on commodity (Hallman, 2000)

Most advanced stage	Objective of treatment
Egg	Prevent development beyond first instar
Early instar (simple metamorphosis)	Prevent late instar or adult
Early instar (complete metarmophosis)	Prevent late instar, pupariation, or pupation
Late instar	Prevent pupation or adult emergence
Pupa	Adult sterility
Adult	Sterility

6.2.1 Irradiation for Bactrocera fruit flies

The most tolerant stage to irradiation is the most advanced stage of the larval development and the third larval instar is considered the most advanced stage in fruit flies (Ross and Engeljohn, 2000). Table 6.2 gives recommended doses to control fruit flies in fruit and vegetables.

Table 6.2: Irradiation doses to control fruit flies in fresh fruit and vegetables (Ross and Engeljohn, 2000)

Scientific name	Common name	Dose (Gy)
Bactrocera dorsalis	Oriental	250
Ceratitis capitata	Mediterranean	225
Bactrocera cucurbitae	Melon	210
Anastrepha suspensa	Caribbean	150
Anastrepha ludens	Mexican	150
Anastrepha oblique	West Indian	150
Anastrepha serpentina	Sapote	150
Bactroceri tryoni	Queensland	150
Bactroceri jarvisi	No common name	150
Bactroceri latifrons	Malaysian	150

The recommended dosages for fruit flies are generic, as outlined in Table 6.2. They do not take into consideration the type of fruit that is being irradiated (Ross and Engeljohn, 2000). In cases where more than one species of fruit flies are involved it is recommended to use the dose for the most tolerant species (Ignatowicz and Brzostek, 2002).

6.3 HEAT TREATMENT

Heat treatments have been used for the past 70 years to disinfest fruit of quarantine pests (Hallman, 2000). Heat treatment was first developed when Baker and his co-workers developed the vapour heat treatment for treatment against the med fly in 1929 (Couey, 1989). The simplicity and non chemical use of heat treatments makes it easy to adapt to developing countries and are also appealing to consumers (Couey, 1989). Heat treatment is based on exposing the fruit to a specific temperature for a specified period taking into consideration the pest and the type of fruit to be treated. Heat treatment is done in three ways: vapour; forced hot air and hot water immersion (Lurie, 1998). When incorrectly applied heat treatment can result in to browning of fruit, uneven ripening of the fruit and the breakdown of the fruit flesh (Jacobi *et al*. 2001).

6.3.1 Vapour heat treatment (VHT)

VHT method involves heated air that is almost saturated with water vapour at temperatures of 40 – 50 º C (Lurie, 1998). The vapour is passed through a stream in overhead conveyer pipes. The vapour condenses on the skin of the fruit, the heat is then conducted to the mesocarp of the fruit thereby killing the eggs and larvae of the fruit flies (Jacobi *et al.*, 2001). VHT is to be applied according to tested treatment temperatures as different mango varieties have different disinfestation temperature and duration regimes as outlined in Table 6.3.

Table 6.3: VHT treatment temperatures and duration for certain mango varieties (Jacobi *et al.*, 2001)

Mango Variety	Core Temperature	Duration
'Carabao' from the Phillipines	46º C	10 minutes
'Irwin and Haden' from Taiwan	46.5 º C	30 minutes
'Nam Klang Wu' from Thailand	46.5 ºC	10 minutes

The Japanese authorities accepted a treatment of 47º C for 15 minutes for Kensington mangoes (Heather *et al.*, 1997). The Australian import requirement for mangoes from the Philippines to mitigate against *B. cucurbitae*, *B. occipitalis* and *B. philippinensis* are 46°C for 10 minutes (AQIS, 1999).The proliferation of different treatment regimes necessitates the development of new and harmonised generic treatments.

6.3.2 Forced Hot Air Treatment (FHAT)

The FHAT method uses heat that is directed from a source, usually a heated chamber, to the stacked fruit (Lurie, 1998). The FHAT is preceded by a pre warming time (approach time) where the fruit is warmed up to a certain temperature in preparation for the FHAT. Conditioning of mangoes at 40ºC prior to the FHAT accelerates ripening but also improves the total quality of the fruit (Jacobi *et al*., 2000).

The fruit is then subjected to the treatment (holding period) in a heated chamber. The hot air is moved through conduction to the core of the fruit (Jacobi *et al.*, 2001). The conduction is slower as compared to the vapour treatment. The fruit is then subjected to a cooling period after treatment. The relative humidity should be regulated in order to prevent the fruit from shriveling (Jacobi *et al.*, 2001). Papayas transported from the Hawaii to the mainland United States of America are subjected to this treatment (Armstrong *et al.*, 1989).

6.3.3 Hot Water Immersion Treatment (HWT)

Water is an effective heat transfer medium, with proper circulation the heat is uniformly transferred to the fruit (Couey, 1989). HWT is a method that involves submerging the fruit in a hot water medium (Lurie, 1998). The transfer is through conduction to the core of the fruit as the water heats the skin of the fruit and then the heat moves through conduction to the core of the fruit (Lurie, 1998).

HWT is effective at a temperature range of 43 – 46 ºC depending on the target pests, the type and size of the fruit (Jacobi *et al.*, 2001). HWT efficacy is also dependant on the knowledge of thermal susceptibility of target insects, the engineering principles that govern the thermal energy delivery methods and understanding of thermal effects on product quality (Tang *et al.*, 2000). Apart from controlling fruit flies, HWT controls fungal diseases like anthracnose and stem end rot (Couey, 1989).

Advantages of HWT (Jacobi et al 2001):

- Easy to set up for many industries including developing countries.
- Has a short treatment time.
- Simultaneously cleans exudates from mangoes.
- Easy to accurately measure core or pulp temperature.
- Higher heat capacity than air and vapour (Bollen and Dela Rue, 1999).
- More effective way of heat transfer (Bollen and Dela Rue, 1999).

Heat treatment has also disadvantages especially when treating mango fruit. The high temperature leads to the browning of fruit. HWT duration and temperature levels must be carefully chosen and monitored (Jacobi *et al.*, 2001).

6.4 METHYL BROMIDE

Methyl bromide (MeBr) is the mostly used fumigant to control pests (Marcotte, 1998). Methyl bromide is used to control pests in food, agricultural and forestry commodities after harvest, during storage or transportation and/or as a quarantine measure during importation of regulated articles (Marcotte, 1998). The use of methyl bromide is presently limited due to the ozone depleting properties of the fumigant (Taylor, 1994). Parties to the Montreal Protocol have classified MeBr to be ozone depleting gas and have initiated phasing it out (Marcotte, 1998).

This phase out has exemptions, especially to developing countries and for preshipment and quarantine measures. Countries are considering alternatives to methyl bromide as a quarantine measure. Most methyl bromide is used as a mitigation treatment for the export of perishable products like fruit, vegetables and cut flowers (Marcotte, 1998)

6.5 COLD TREATMENT

Cold treatment has been used for mitigation against fruit flies since the 1950s (USDA, 1957). The USDA treatment manual indicates that exposing fruit to temperature regimes below 2.2 ° C for varying periods will ensure that the fruit is treated against fruit flies (www.aphis.usda.gov). These temperature regimes are used by South Africa in mitigating for fruit flies when exporting to China, Israel, Japan, South Korea and USA for a variety of commodities (www.nda.agric.za). South African citrus fruit exported to Japan is subjected to a treatment regime of maintaining the pulp of the fruit between – 0.6°C ± 0.6°C for 12 days as treatment against Mediterranean fruit fly (www.nda.agric.za).

The USDA cold treatment regimes are:

- 0 ± 0.5 C for at least 14 days.
- 1 C ± 0.5 C for at least 16 or ,in the case of lemons 14 days, or;
- 2C ± 0.5 C for at least 18 days or;
- 3.0 C ± 0.5 C for at least 22 days.

Although these temperature regimes were tested on experimental basis, commercial implementation faced challenges over the past two years. The USA previous cold treatment schedules were extended by 2 days for most approved temperatures as a result of interceptions in 2001 of live Mediterranean fruit fly larvae in Clementine's that were imported from Spain (www.aphis.usda.gov). Except for this interception of fruit flies, an interception of False Codling Moth larvae in citrus fruit from South Africa in 2005 has also led to the particular temperature regime extended by two days.

6.6 DISCUSSION

Failure of a treatment can lead to entry and establishment of quarantine pests (Magan and Hallman, 1999). Therefore the confidence level and the ALOP placed on the mitigation treatments by the importing country are usually high.

The type of treatment that can be applied is based on the concept of equivalence. The importing country is obliged to accept treatment that provides the same level of plant health protection as those familiar to the importing country. Ionizing irradiation, heat treatment, methyl bromide treatment and cold treatment can be used as mitigation treatment for fruit flies. These treatments are to be applied in the country of origin.

Ionizing irradiation is fruit fly species specific and where there is a wide range of quarantine fruit flies of concern, the most resistant fruit fly species dosage has to be used. Ionizing irradiation presents a system that is easy to interpret and use. The only deterrent to exporting countries may be the cost of implications of irradiation treatments.

Research in heat treatments is increasing due to cost of alternative measures, the regulatory restrictions of chemical use and consumer demand for chemical free fruit. Heat treatments are not only commodity specific but are also cultivar specific. In applying heat treatment, the temperature has to be precise to the commodity and cultivar. The lack of generic treatments renders temperature choices for cultivars that were not researched difficult as the treatments have to be researched before determining an ALOP.

With the banning of methyl bromide other than for phytosanitary measures, this fumigant’s future also looks bleak due to consumer demands and countries’ regulatory restrictions. Methyl bromide effectiveness is dependent on temperature, the commodity and the duration of the fumigation. The dependence of this type of treatment on temperature renders this type of treatment difficult in fluctuating temperatures which may influence the efficacy of the treatment.

Cold treatment is usually done in transit and would not be considered for hand luggage unless the treatment is done in the country of origin. This type of treatment may be impractical for hand luggage.

With heat treatments considered least expensive HWT and easy to apply, the next chapter will test the efficacy of this type of treatment as one of the option that can be accepted for fruit fly disinfestation for mango consignments from India and Kenya.

CHAPTER 7

VERIFICATION OF HOT WATER TREATMENT

7.1 INTRODUCTION

HWT is effective at a temperature range of 43 – 46 ºC depending on the target pests and the type and size of the fruit (Jacobi *et al.* 2001). The South African phytosanitary requirement for mangoes is HWT at 47° C held for 12 minutes comparable to the treatment recommended by Jacobi *et al*. (2001). Australian requirements for HWT are 46°C held for 10 minutes. The efficacy of HWT is dependent on the size of the fruit and the temperature and hence a test for the efficacy of HWT on fruit flies was essential to give a degree of confidence on the possibility of recommending HWT for the treatment of fruit flies.

7.2 MATERIALS AND METHOD

The *Bactrocera* fruit flies are quarantine pests and cannot be imported for testing and therefore Mediterranean fruit flies were used for laboratory testing. The treatments applied were 46 °C for 10 minutes as specified in the Australian manual AQIS, (1990) and the South African phytosanitary conditions for importing fresh mangoes that require 47°C for 12 minutes for the treatment of fruit flies.

7.2.1 The fruit

Ten boxes of green Tommy Atkinson mango fruit weighing between 351 and 550 grams per fruit originating from Sandbult Farm, Malelane in Mpumalanga were obtained and transferred into a laboratory at O.R. Tambo International Airport. Each box contained 9 uniform and unblemished fruit. The fruit were weighed to confirm compliance with the weight given on the pack and all fruit complied. The fruit was kept at 24°C for 24 hours before commencement of the experiment.

7.2.2 The larvae

Two small containers with live newly hatched Mediterranean fruit fly, *Ceratitis capitata* Weidemann larvae were obtained from the Citrus Research Institute in Nelspruit. The larvae were kept for five days at 27°C in the laboratory to allow them to reach the third larval instar before proceeding with the experiment.

7.2.3 The experiment

The experiment was conducted in the laboratory facility of the Department of Agriculture at OR Tambo International Airport. The boxes were divided into two batches of five boxes. This was done to accommodate two experiments, at pulp temperatures of 46°C and 47°C respectively.

Experiment 1

Five boxes were used for this experiment. Each box was treated as a separate batch. The first batch was used to determine the average time required to achieve 46°C. Three waterproofed temperature sensors were inserted into the larger fruit of the batch of nine fruit. After this was determined, the fruit were then prepared for the HWT treatment. The water bath temperature was set at 46.1°C. The first batch was reused for the insertion of larvae upon completion of the time determination. The three sensors were also inserted into each batch to verify experimental time.

Experiment 2

Same procedures were used as for experiment 1 except that the temperature for the pulp was 47°C and the water bath temperature was set at 47.1°C.

(a) ***The preparation of the fruit***

The Jang (1996) method of artificially infesting fruit with fruit fly larvae was applied. A small hole was bored into the fruit using a cork borer and the resultant cork being removed from the fruit. The depth of the holes was 3cm and the resultant cork was cut to 1.5 cm to prevent suffocation of the fruit fly larvae.

(b) ***The larvae insertion***

The larvae were removed from the original containers, rinsed with clean running water and then placed into the bored holes by means of a micro spoon and an insect brush was used to brush the larvae into the fruit. The larvae were then brushed into the fruit using an insect brush. Fourteen larvae were inserted per fruit and 1 260 healthy looking larvae were used as Dukas *et al*., (2001) reported that Mediterranean fruit flies could lay up found 14 -21 eggs per fruit. The fruit plugs were then reinserted and then a water sealant used to ensure waterproofed fruit.

(c) ***The immersion of the fruit***

Each batch of fruit was immersed in water, taking into consideration the time it took to reach the required temperature for either experiment 1 or 2. To monitor and verify the time that was achieved though the average time test, 3 temperature probes were inserted in the biggest mangoes. After the pulp core temperature of the fruit reached 46°C and 47°C respectively the temperature was maintained for ten and twelve minutes respectively.

(d) ***The efficacy check***

The fruit was left to cool and the plugs were removed to verify whether any larvae were still alive. When the plug was removed, the holes were checked for any water leakages. The fruit together with the larvae were then bedded with commercial river sand to mimic soil conditions. The fruit and the larvae were then stored at 22° C in a controlled laboratory environment. The purpose was to observe any pupation or emergence by possible survivors. The soil was sifted on a daily basis for two weeks to search for pupae.

Figure 7.1: Mangoes prepared for HWT

7.3 RESULTS

For experiment 1, the average time taken for the fruit to reach the core temperature of 46°C was 61 minutes and the whole experiment took 71 minutes per batch. Experiment 2 fruit averaged 64 minutes to reach the core temperature of 47°C and the experiment's duration was 76 minutes.

Both the experiments were successfully completed as there were no live larvae detected upon removal of the plugs and no pupae were detected after sifting through the sand daily sifting for two weeks.

There were no differences between the efficacy of temperature regimes of the core temperature at 46°C and 47°C for the med flies.

7.4 DISCUSSION

While the experiment showed good results against the Mediterranean fruit fly, it was not tested against the *Bactrocera* fruit flies due to their quarantine status in South Africa. It is also noted that the HWT of Bactrocera fruit flies are at lower temperatures.

HWT of mangoes is commodity and cultivar specific. The experiment conducted was on Tommy Atkins mango cultivar as the South African import requirements were not cultivar specific. Grovė, Steyn and de Beer (1998) and the USDA, (2003) used standard treatments as 75 minutes for mangoes less < 500 g and 90 minutes for mangoes > 500 g. Therefore, other than the cultivar, weight can also be used as a determinant of the temperature regime and duration of the treatment.

Based on the South African HWT regime the highest temperature regime and duration is prescribed for mango consignments. It can therefore be argued that there is a possibility to develop generic HWT depending on the effect that the treatment will have on the fruit.

7.5 CONCLUSION

The import of plant and plant products as hand luggage has not yet been quantified in South Africa. This survey only concentrated on midweek flights from three countries. The plants and plant products intercepted through this survey indicate that the risk posed by plants and plant products is high. The future quantification of these plant and plant products will allow South Africa to assess the risks posed by these commodities. Once these risks are determined a risk profile can be developed and intensification of inspection can be done on those flights likely to carry high risk products.

The survey has also raised an issue of the promotion and awareness of the travelling public in terms of restrictions on plants and plant products. An aggressive promotion and awareness programme needs to be established. The programme has to be aimed at the airport role players, especially the airlines for dissemination to the travelling public.

Since the plants and plant products are sourced from other countries, South Africa has to inform all its trading partners on the restrictions on plant and plant products carried as hand luggage. The embassies where visas are issued are to be targeted both locally and abroad.

As prohibitions lead to an increase in smuggling, a PRA on the commodities imported as hand luggage has to be conducted and where risk is identified, an appropriate ALOP has to be provided, even for hand luggage. Prohibition must be used as the last option to control risk associated with plants and plant products imported as hand luggage.

CHAPTER 8

GENERAL DISCUSSION

The risks posed by plants, plant products and other regulated articles may be high for a country's agricultural industry and the environment. Government is expected to manage these plant health risks while not impeding trade (WTO Agreements Series, 1998; IPPC 1997). In an attempt to manage these risks, it is noted that some countries may use phytosanitary measures as technical barriers to trade or force other countries to accept their phytosanitary measures (Miller, 2003; Miljkovic; 2005). Countries are therefore encouraged to adopt an ALOP that will ensure minimal impact on trade and apply prohibition as the last option of risk management (Matthews, 2004; Griffin, 2005). A PRA is the only scientific method that can be used to determine and propose risk management options for identified risks (James and Anderson, 1998). National phytosanitary legislation has to be aligned with the international obligations of the IPPC.

Hand luggage from Cameroon, India and Kenya flights were viewed as high risk. This led to a pest risk initiation phase, which was discussed in **Chapter 3.** A variety of plant products were intercepted in hand luggage from 155 flights. The Agricultural Pests Act, 1983, prohibits in terms of pre border activities, the importation of these commodities without an import permit. The importation was hence in contravention of the Agricultural Pests Act, 1983.

Travellers claimed that they were not familiar with the import requirements of South Africa, a claim also made in Australia and reported by Stanton (2004). Awareness programmes to inform the travelling public may alleviate the levels of the uninformed travelling public. The interceptions as shown in Table 3 were too high; signifying the risk posed by aircraft transportation, which is faster and therefore the quarantine pests can survive in this mode of transport and be introduced into a new area (Hopper and Campbell, 1989). The use of methods such as the sniffer dogs and the X ray machines may assist in detecting larger quantities of illegal hand luggage imports.

The introduction potential is also reliant on the pest being associated with the commodity at origin and therefore **Chapter 4** assessed the probability of the association of the pest with the commodity at origin. The pest risk assessment in **Chapter 4** qualitatively indicated the phytosanitary risks associated with the commodities that were identified through interceptions as in **Chapter 3.** These risks were identified as high although there are still question marks in terms of the association of the pest with the fruit (commodity). Pests may occur on the host plant but not on the exported commodity as noted on the data generated by the CPC (2003). This gives ascension to the critics who have queried that a PRA is not entirely based on scientific arguments (Miljkovic, 2005; Miller, 2003). This area of pest risk assessment will require earnest attention from scientists and regulators to avoid disputes.

In **Chapter 5** the scope of pest risk management was limited to the *Bactrocera* fruit flies and therefore a further pest risk assessment for the Bactrocera fruit flies was compiled.

The pest risk assessment was based on the EPPO system (McLeod and Baker, 2003). The scores based on the introduction, establishment and spread potential were high, although only 8 critical areas were evaluated. The areas of concern were around the adaptability of these fruit flies to different temperature regimes, which makes South Africa a probable area for establishment. In evaluation of these fruit flies, the question that begs to be answered is since the commodities intercepted were previously imported into South Africa without any inspections, whether these flies have not yet entered South Africa. This calls for quarantine fruit fly surveillance in terms of the post border activities.

Since the WTO and the IPPC are against the concept of zero risk, **Chapter 6** evaluated the prevalent pest risk management options. Most of these measures are temperature based except for methyl bromide treatment and irradiation. While irradiation is convenient and there are facilities close to OR Tambo International Airport, it is an expensive mitigation treatment. Methyl bromide is easy to use but also expensive while cold treatment requires specialised containers and technically competent technicians. Hence hot water treatments were evaluated for effectiveness, efficiency and effect on the quality of the fruit. For FHAT and VHT, specialised equipment is required while HWT can be easily performed with existing resources.

HWT was evaluated at the test rooms of the Department of Agriculture at O.R. Tambo International Airport as outlined in **Chapter 7**. The experiment was conducted using Mediterranean fruit fly larvae as the Bactrocera fruit flies are quarantine pests in South

Africa and cannot be imported. Pulp temperature held at 46°C for 10 minutes and alternatively held at 47°C for 12 minutes were found effective against the Mediterranean fruit fly. But the import conditions in terms of the Agricultural Pests Act, 1983, gives conditions where the pulp temperature has to be checked at 45 minutes, 90 minutes and 102 minutes, while the mango fruit that were used for the experiment reached the heat treatment “start” temperature within 60 minutes of immersion. This points out that the size of the fruit has to be taken into consideration while prescribing heat treatment. Heat treatment also has to be pest and variety specific to be certain of its efficacy.

In the light of these findings, future research in this field should focus on:

- The profiling of other flights landing at OR Tambo International Airport.
- The quantitative assessments of quarantine pests identified as high risk.
- The evaluation of the efficacy HWT on different varieties and against different pests.
- Post border detection surveillance for exotic fruit flies.
- The bio security and economic linkages between pre border, border and post border activities in the Republic of South Africa.

SUMMARY

The probabilities of finding agricultural products in a passenger aircraft is 50% or lower (www.cast-science.org). Aircraft has been identified as a probable carrier of exotics that may be detrimental to the bio security of an area (Landis, 2003). Taking into consideration the framework that governs the plant health and life issues, the WTO-SPS, IPPC, CBD and the Agricultural Pests Act, 1983, an evaluation on the phytosanitary risks posed by commodities imported as hand luggage had to be conducted.

The objectives of this study were to:

- Profile and conduct a pest risk assessment on plant and plant products imported from Cameroon, Kenya and India as possible pathways for quarantine pests
- Identify probable pathways for the *Bactrocera* fruit flies from the passenger luggage from the targeted flights
- Determine the probability of *Bactrocera* fruit flies entry, establishment and spread in South Africa
- Evaluate probable phytosanitary management options for post harvest treatment of *Bactrocera* fruit flies

There were high interceptions of fruit, followed by vegetables from 155 flights from the three countries. From Cameroon, plantains, yam tubers and cassava leaves were imported in large quantities.

Most fruit interceptions from India were mangoes, lemons and dates while the interceptions from Kenya were for pineapples, mangoes, okra, pumpkin gourds and garlic.

The pest risk assessment on these commodities yielded a range of quarantine pests: insects, mites, bacteria, fungi, viruses and weeds. It would have been impractical to subject all the identified quarantine pests to a pest risk management stage and only *Bactrocera* fruit flies were considered. *Bactrocera* fruit flies associated with the commodities intercepted were *B. carambolae*, *B. caryae*, *B. cucurbitae*, *B. dorsalis*, *B. dorsalis* complex, *B. invadens* and *B. zonata*.

These fruit flies were subjected to a quantitative pest risk assessment which confirmed the high risk of the Bactrocera fruit flies introduction, establishment and spread potential. Hence the existing mitigation treatments for fruit flies were evaluated for efficacy. Most of the treatment are temperature based and are expensive to conduct cost effectively. Such measures include irradiation, hot water treatments, methyl bromide and cold treatment.

An experiment was conducted using Mediterranean fruit fly third instar larval insects to verify the efficacy of HWT where the pulp is maintained at 46°C and 47° C for 10 minutes and 12 minutes respectively. At both temperature regimes both treatments were found to be effective.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to the following parties who offered assistance, encouragement and support during the preparation of this thesis.

Prof. P S Hammes, my supervisor for his encouragement and support during my studies. If it was for him this thesis would not have been written.

Mr. M A Holtzhausen, my co-supervisor, mentor and colleague who was available for advice anytime of day and night.

The staff of the Department of Plant Production and Soil Science and my fellow student colleagues for their assistance and unwavering support.

The Department of Agriculture for funding my studies and allowing me to use Departmental resources, your contribution is highly appreciated.

My colleagues T P Mnguni and M J Manyuwa for assisting with the data collection and without you guys the commodity profiling would have been only a wish.

To my wife Mantšhe, my children Tiro and Molemo for their patience and understanding.

To God Almighty for abundantly providing me with strength and blessings.

REFERENCES

AEGERTER, A.F. and FOLWELL R.J., 2000. Economic aspects of alternatives to methyl bromide in the post harvest and quarantine treatment of selected fruit. *Crop Protection,* **19**: 161 – 168.

ARMSTRONG, J.W., HANSEN, J.D., HU, B.K. and BROWN S.A., 1989. High temperature, forced-air quarantine treatment for papayas infested with tephritid flies (Diptera: Tephritidae). *J. Econ. Entomol.,* **82**: 1667 – 1684.

ARMSTRONG J.W., SILVA S.T. and SHISHIDO V. M., 1995. Quarantine cold treatment of Hawaiian Carambola fruit infested with Mediterranean fruit fly, melon fly, or oriental fruit fly (Diptera: Tephritidae) eggs and larvae. *J. Econ. Entomol.,* **88**: 683-687.

AUSTRALIAN QUARANTINE INSPECTION SERVICES, 1999. Final Import Risk Analysis on the proposal to change the treatment for mango (*Mangifera indica* L.) fruit from the Republic of the Philippines. AQIS, Australia.

BAKER, R.T., COWLEY, J.M., HARTE, D.S. and FRAMPTON, E.R. (1990). Development of Maximum Pest Limit for fruit flies (Diptera: Tephritidae) in produce imported into New Zealand. *J. Econ. Entomol.,* **83**: 13 – 17.

BOLLEN, A.F. and DELA RUE B.T., 1999. Hydronamic heat transfer – a technique for disinfestation. *Post Harvest Biology and Technology,* **17**: 133 -141.

CANNON, R.M., 1998. Sampling to comply with Maximum Pest Limit. *Biometrics,* **54**: 847 – 858.

COUEY, H.M., 1989. Heat treatment for the control of post harvest diseases and insect pests of fruit. *HortScience.,* **24**:198-202.

DREW, R.A.I. and D.L. HANCOCK., 1994. The *Bactrocera dorsalis* complex of fruit flies (Diptera: Tephritidae: Dacinae) in Asia. *Bull. Entomol. Res*., **2**: 68.

DREW, R.A.I., TSURUTA, K. and WHITE I.M., 2005. A new species of pest fruit fly (Diptera: Tephritidae: Dacinae) from Sri Lanka and Africa. *Africa Entomology* 1**3**, 149-154.

DUKAS, R., PROKOPY R.J. and DUAN J.J., (2001). Effects of larval competition on survival, growth in Mediterranean fruit flies. *Ecological Entomology,* **26**: 587-593.

FERRAR, P., 2004. Australian Entomology, isolated or in touch with the rest of the world? *Australian Journal of Entomology* **43**: 329 – 333.

FLETCHER, B.S; 1989. Ecology; movements of tephritid fruit flies In: World Crop Pests. *Fruit Flies, their biology; natural enemies and control* (Ed. by Robinson, A.S. and Hooper, G) 209 – 219 Elsevier, Amsterdam, Netherlands.

FLORIDA DEPARTMENT OF AGRICULTURE AND CONSUMER SERVICES, 2003. Fruit fly pests.

GROVÈ, T, STEYN, W.P., and DE BEER, M.S., 1998. Fruit fly disinfestations with cold treatment. Agricultural Research Council, Nelspruit, South Africa, Institute for Tropical and Sub Tropical Crops, Neltropika, pp. 12.

GUPTA, K. and KETHARPAL, R.K., 2005. Facilitating trade in fresh fruit and vegetables by developing disinfestation protocols: a case study. *EPPO Bulletin*, **35**: 501 – 509.

HALLMAN, G.J., 2000. Factors affecting quarantine heat treatment efficacy. *Post Harvest Biology and Technology,* **21**: 95-101.

HEATHER, N.W., CORCORAN, R.J. and KOPITTKE, 1997. Hot air disinfestations of Australian 'Kensington' mangoes against two fruit flies (Diptera: Tephritidae). *Post Harvest Biology and Technology* 10: 99 – 105.

HEDLEY, J., 1990. Improved plant quarantine using bilateral quarantine agreements for the exclusion of high risk pests. *IPPC Plant Protection Bulletin* **38**: 127 – 133.

HEESTERBEEK, J.A.P. and ZADOKS J.C., 1987. Modeling pandemics of quarantine pests and diseases: problems and perspectives. *Crop Protection*, **6**: 211 – 221.

HOPPER, B.E. and CAMPBELL W.P., 1989. Crop Protection information in the NAPPO Region. *Crop Protection Information: an international perspective*, **7**: 227 – 228.

IGNATOWICZ, S. and BRZOSTEK, G., 2002. Use of irradiation as quarantine treatment for agricultural products infested by mites and insects. International Journal of Radiation Applications and Instrumentation Part C. *Radiation Physics and Chemistry,* **35**: 263-267.

IPPC, 1995. Guidelines for pest risk analysis. FAO.

IPPC, 1997. The International Plant Protection Convention Text. FAO.

IPPC, 1998. Determination of pest status in an area. FAO.

IPPC, 1999. Requirement for the establishment of pest free places of production and pest free production sites. FAO.

IPPC, 2001. Guidelines for notification of non-compliance and emergency action. FAO.

IPPC, 2002. The use of integrated measures in a systems approach for pest risk management. FAO.

IPPC, 2004a. Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms. FAO.

IPPC, 2004b. Guidelines for a phytosanitary import regulatory systems. FAO.

IPPC, 2005a. Glossary of phytosanitary terms. FAO.

IPPC, 2005b. Guidelines for inspection. FAO.

IWAIZUMI, R, 2004. Species and host record of the *Bactrocera dorsalis* complex (Diptera: Tephritidae) detected by the plant quarantine of Japan. *Applied Entomology and Zoology*, Vol. 39: 327 – 333.

JACOBI, K.K., MACRAE, E.A. and HETHERINGTHON, S.E., 2001. Post harvest heat disinfestation in mangoes. *Scientia Horticulturae,* 89: 171-193.

JACOBI, K.K., MACRAE, E.A. and HETHERINGTON, S.E., 2001. Loss of heat tolerance in 'Kensington mango' following heat treatments. *Post Harvest Biology and Technology,* **21**: 321- 330.

JACOBI, K.K., MACRAE, E.A. and HETHERINGTON S.E., 2000. Effects of hot air conditioning of 'Kensington' mango fruit on the response to hot water treatment. *Post Harvest Biology and Technology,* **21**: 39-49.

JAMES, S. and ANDERSON K., 1998. On the need for more economic assessment of quarantine policies. *The Australian Journal of Agricultural and Resource Economics,* **42**: 425 – 444.

JANG, E.B., 1996. Systems approach to quarantine security: Post harvest application of sequential mortality in the Hawaiian grown "Sharwil" avocado system. *J. Econ. Entomol.,* **89**: 950 – 956.

KAPOOR, V.C., 2002. Fruit-fly pests and their present status in India. Proceedings of the 6th International Fruit Fly Symposium. 6-10 May 2002, Stellenbosch, South Africa, pp.23-33.

KIRITANI, K., 1998. Exotic Insects in Japan. *Entomological Science*, **1**: 291 – 298.

KOEMAN, J.H. and ZADOKS, J.C., 1999. History and future of plant protection policy. *Plants and Politics,* pp 46.

LANDIS, N.G., 2005. Regional Scale Ecological Risk Assessment using the Relative Risk Model.

LURIE, S., 1998. Post harvest heat treatments. *Post Harvest Biology and Technology,* **14**: 257 – 269.

MCDONALD, R.E., MILLER W.R., and MITCHAM, E.J., 1993. Temperature as a quarantine treatment of Carribean Fruit Flies (Diptera: Tephritidae) and its effect on Product condition and Quality. *Florida Entomologist*, **76**: 218 – 224.

MACLEOD, A. and BAKER, R.H.A., 2003. The EPPO Pest Risk Assessment Scheme: Assigning descriptions to scores for the questions on entry and establishment. *EPPO Bull*. **33**: 313 – 320.

MANGAN, R.L. and HALLMAN G.J.,1998. Temperature treatments for quarantine security: New approaches for fresh commodities. *In temperature sensitivity in Insects and Application in Integrated Pest Management, ed,* pp 201 – 234, Boulder Co: Westview.

MARCOTTE, M., 1998. Irradiation as a disinfestations method – update on methyl bromide phase out, regulatory action and emerging opportunities. *Radiation Physics and Chemistry,* **52:** 85-90.

MATTHEWS, G.A., 2004. Principles of Plant Health and Quarantine. *Crop Protection* **23**: 369.

MATHYS, G. and BAKER, E.A., 1980. An appraisal of the effectiveness of quarantines. *Annual Review of Phytopathology,* **18**: 85-101.

MAYNARD, G.V., HAMILTON J.G. and GRIMSHAW J.P., 2004. Quarantine – Phytosanitary, Sanitary and Incursion Management: An entomological perspective. *Australian Journal of Entomology,* **43**: 318 – 328.

MOY, J.H. and WONG L., 2002. The efficacy and progress in using radiation as a quarantine treatment of tropical fruit – a case study in Hawaii. *Radiation Physics and Chemistry,* **63**: 397- 401.

MILLER, C.E., 2003. Notes on the effectiveness of risk mitigation measures *FCFR* 319.37 – 8ce.

MILJKOVIC, D., 2005. Sanitary and Phytosanitary Measures in International Trade: Policy Considerations vs. Economic Reasoning. *International Journal of Consumer Studies*, **29**: 283 – 290.

MYBURGH, A.C., 1989. Crop Pests in Southern Africa. Plant Protection Research Institute, Department of Agriculture and Water Supply, Pretoria, South Africa.

MWATAWALA, M.W., WHITE, I.M., MAERERE, A.P., SENKONDO, E.J. and DE MEYER, M., 2004. A new invasive Bactrocera species (Diptera: Tephritidae) in Tanzania. *African Entomology,* **12**:154-156.

NAI-ZHONG, C. and ZUO-RUI, S., 2003. Computer-aided consultation and identification system for insect pests infesting fruit. *EPPO Bulletin,* **33**: 321-323.

NEVEN, L.G. and DRAKE, S.R., 2000. Comparison of alternative post harvest treatments for sweet cherries. *Post Harvest Biology and Technology,* **20**: 107- 114.

NORTON, G.A., 1976. Analysis of decision making in crop protection. *Agro-Ecosystems,* **3**: 27- 44.

NUNN, M., 1997. Quarantine Risk Analysis. *The Australian Journal of Agricultural and Resource Economics*, **41**: 559-578.

OERKE, E.C., DEHNE, H.W., SCHONBECK, F. and WEBER, A., 1994. Crop Production and Crop Protection. Elsevier, Amsterdam, 808pp.

PASIECZNIK, N.M., SMITH, I.M, WATSON, G.W., BRUNT, A.A., RITCHIE, B. and CHARLES, L.M.F., 2005. CABI/EPPO distribution maps of plant pests and plant diseases and their important role in plant quarantine. *EPPO Bulletin,* **35**: 1-7.

PENÃ, J.E., MOHYUDDIN, A.I. and WYSOKI, M., 1998. A review of the pest management situation in mango agrosystems. *Phytoparasitica,* **26**: 129-148.

PERELMAN, M., 1975. Social valuation of pest management strategies. *Agro – Ecosystems*, **2**: 153 – 155.

PIMENTEL, D., MACNAIR, S., JANECKA, J., WIGHTMAN, J., SIMMONDS, C., O'ÇONNEL C., WONG, E., RUSSEL, L., ZERN, J., AQUINO T. and TSOMONDO T., 2001. Economic and environmental threats of alien plants, animal, and microbe invasions. *Agricultural Ecosystems and Environment* **84**: 1-20.

QUINLAN, M.M., 2002. Trends in international phytosanitary standards: potential impact on fruit fly control. Proceedings of the 6th International Fruit Fly Symposium. 6-10 May 2002, Stellenbosch, South Africa, pp.195-200.

REICHELDERFER, K. and BOTRELL, D.G., 1985. Evaluating socioeconomic effects of pests. *Crop Protection* **4**: 281 – 297.

REJMÀNEK, M., 2000. Invasive Plants: Approaches and predictions. *Austral Ecology,* **25**: 497 – 506.

ROSS, R.T. AND ENGELJOHN D., 2000. Food irradiation in the United States: Irradiation as a phytosanitary treatment for fresh fruit and vegetables and for the control of microorganisms in meat and poultry. *Radiation Physics and Chemistry*: Vol. 57 (3), 211- 214 (4).

SIMBERLOFF, D., 2000. Global climate change and introduced species in United States forests. *The Science of the Total Environment,* **262**: 253 -261.

SMITH, I.M., 2004. Official control of quarantine pests in the EPPO region. *EPPO Bulletin* **34**: 423 – 424.

STANTON., M., 2004. Responsiveness and Crisis Management in Regulatory Protection and Prevention. *Australian Journal of Public Administration,* **64**: 34-36.

STRAND, J.F., 2000. Some agrometeorological aspects of pests and disease management for the 21st century. *Agricultural and Forest Meteorology,* **103**: 73-82.

TANG, J., IKEDIALA, J.N., WANG, S., HANSEN, J.D. and CAVALIERI R.P., 2000. High-temperature-short time thermal quarantine methods. *Postharvest Biology and Technology,* **21**: 129-145.

TANNER, C., 1997. Principles of Australian Quarantine. *The Australian Journal of Agricultural and Resource Economics*, **41**: 541 – 558.

TANNER, C. and NUNN M., 1998. Australian quarantine post Nairn Review. *The Australian Journal of Agricultural and Resource Economics*, **42**: 445 – 458.

TAYLOR, R.W.D., 1994. Is there any future for this noteworthy fumigant?

USDA APHIS, 1990. Plant Protection and Quarantine Manual. USDA, Hyattsville.

USDA APHIS, 1993. Plant Protection and Quarantine treatment Manual. United States Department of Agriculture - Animal and Plant Health Inspection Service.

WHITE, I.M. and ELSON-HARRIS, M.M., 1992. Fruit flies of economic importance: their identification and bionomics. CAB International, Wallingford, Oxon, UK and the Australian Center for Agricultural Research, Canberra, Australia.

VARGAS, R.I., WALSH, W. A., KANEHISA, D., JANG, E.B. and ARMSTRONG J.W., 1997. Demography of four Hawaiian fruit flies (Diptera: Tephritidae) reared at five constant temperatures. *Annals of the Entomological Society of America,* **90**: 162-168.

VARGAS, R.I., WALSH, W.A., KANEHISA, D., STARK, J.D. and NISHIDA, T., 2000. Comparative demography of the three Hawaiian Fruit flies (Diptera: Tephritidae) at alternative temperatures. *Annals of the American Entomological Society,* **93**: 75 – 81.

VERGHESE, A., MADHURA, H.S., KAMALA JAYANTHI, P.D. and STONEHOUSE, J.M., (2002). Proceedings of the 6th International Fruit Fly Symposium. 6-10 May 2002, Stellenbosch, South Africa, pp.317-324.

WILLIS, A.J., MEMOTT, J. and FORRESTER, R.I.; 2000. Is there evidence for the post invasion evolution of increased size among invasive plant species.
Ecology Letters, **3**: 275 – 283.

WHINAM, J., CHILCOTT, N. and BERGSTROM, D.M., 2005. Subantarctic hitchhikers: expeditioners as vectors for the introduction of alien organisms. *Biological Conservation*, **121**: 207-219.

WTO Agreement Series, Sanitary and Phytosanitary Measures, 1998.

YAMAMURA, K. and SUGIMOTO, T; 1995. Estimation of the pest prevention ability of the import plant quarantine in Japan. *Biometrics*, **51**: 482 – 490.

YANG, P., CAREY, J.R. and DOWELL, R.V., 1994. Temperature influences on the development and demography of *Bactrocera dorsalis* (Diptera: Tephritidae) in China *Environmental Entomology*, **23**: 971-974.

www.affa.gov.au. Import risk analysis on Banana fruit from the Philippines.

www.agribusiness.asn.au. An economic evaluation of interstate quarantine protocols for mangoes entering Western Australia.

www.aphis.usda.gov. Crop Bio security Early Warning systems.

www.aphis.usda.gov. The Treatment Manual.

www.ars.usda.gov/research. National Program Annual Report.

www.apsnet.org. International Cooperation in Risk Analysis and Development Regulations.

www.bc.edu. Science and international trade – Third generation scholarship .

www.biodiv.org. Convention on Biological Biodiversity – Text of the Convention.

www.bytesite.com.au. Pest Risk Analysis in developing countries, capabilities and constraints.

www.cabicompendium.org. CABI Crop Protection Compendium, Database, CAB International, Wallingford, UK.

www.cast-science.org. Invasive Pest Species: Impacts on Agricultural Production, Natural Resources and the Environment.

www.epa.gov. 2001. Heat treatments as an alternative quarantine control technologies for perishable commodities.

www.eppo.org. The EPPO Pest List.

www.ippc.int . Guide to the International Plant Protection Convention.

www.nda.agric.za. Export Programmes.

www.spc.int. Import Risk Analysis.

www.tradelaw. WTO Developments.

www.wto.org. Sanitary and Phytosanitary Measures.

www.umwc.umw.edu/geography/100/koppen. Koppen's Climate Classification.

ANNEXURES

ANNEXURE 1

Flight schedules

COUNTRY	DEPARTURE	FLIGHT NUMBER	DAY(S)	EXPECTED TIME OF ARRIVAL
CAMEROON	Douala	UY 808	Wednesday	21:15
KENYA	Nairobi	SA 183 KQ 460	Monday to Friday Tuesday and Thursday	18:10 10:50
INDIA	Mumbai	SA 277	Tuesday and Thursday	06:25