EFFICACY OF LOCALLY FORMULATED BAITS IN MANAGING THE MELON FLY, *Bactrocera cucurbitae* (COQUILLETT) (DIPTERA: TEPHRITIDAE)

BY

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ABSTRACT

Laboratory and field experiments were carried out in Morogoro Region from August 2008 to June 2009 to evaluate effectiveness of locally formulated baits in managing the melon fly, *Bactrocera cucurbitae* (Cocquillett) (Diptera:Tephritidae). An assay was design to determine the quantity of *D. elliptica* that could kill more than 50% of *B. cucurbitae* populations, where by roots of *D. elliptica* were sun dried and prepare a crude extracts then were mixed with brewer's yeast and the other one mixed with molasses at different concentration and time of exposure then administered to the adult of *B.cucurbitae*. LD_{50} value of the extracts of *D. elliptica* in Molasses and Brewer's yeast against *B. cucurbitae* was observed at 24 hours and 36 hours time of exposure at concentrations of 1.5 g/l to 2.5 g/l respectively, mortalities were increased with concentrations and the time of exposure to *D. elliptica* in either Molasses or Brewer's yeast. Completely Randomized Block Design (CRBD) in three locations was used with four treatments each applied on an individual plot. Four weeks after sowing baits were sprayed on the roosting host plant while an insecticide was sprayed on the crop following recommended doses. *D. ellipica* extracts mixed in molasses sprayed on border crop show significance difference compared with the Dimethoate 40 EC sprayed on crop, and Spinosad (GF-120) sprayed on border crop. The efficiency of locally formulated baits in monitoring the *B. cucurbitae* population was tested on plots of watermelon crop. McPhail traps were hung on a wooden pole 1.5 m above the ground and prepared recommended bait solutions were added to each trap. Significant different were observed in the efficacy of brewer's waste, solulys, molasses and Protein baits in monitoring *B. cucurbitae* population. Molasses was proved to be more effective in attracting large means number of *B. cucurbitae* followed by brewer's waste.

DECLARATION

I, LIGHTNESS CHRISTOPHER MURO do hereby declare to the Senate of Sokoine University of Agriculture, that this dissertation is my original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

Lightness Christopher Muro Date

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The above declaration is confirmed

Dr. M. W. Mwatawala Date

(Supervisor)

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DEDICATION

This work is dedicated to my late parents Mr and Mrs Muro who laid the foundation of my education. The work also is dedicated to my husband H. Jarufe who took care of the family during my study. May almighty God bless them all.

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LIST OF ABBREVIATIONS AND SYMBOLS

%	-	Per cent
<	-	less than
>	-	greater than
a.s.l	-	above sea level
AFFI	-	African Fruit Fly Initiatives
ANOVA	-	Analysis of Variance
C˚	-	Degrees Centigrade
CABI	-	Commonwealth Agriculture Bureau International
df	-	Degrees of Freedom
et al,	-	and others
F	-	F- values
FAO	-	Food and Agriculture Organization
Fig	-	Figure
g	-	Grams
IAEA	-	International Atomic Energy Agency
IPM	-	Integrated Pest Management
Kgs	-	Kilograms
LC50	-	Lethal concentration that kills 50 % of test insects
LD50	-	Lethal dose that kills 50 % of test insects
spp	-	Species
SUA	-	Sokoine University of Agriculture
USDA	-	United States Department of Agriculture
var	-	Variety
vs	-	Versus

CHAPTER ONE

1.0 INTRODUCTION

1.1 General Information

Horticulture is the fastest growing agricultural sub-sector in Africa providing income and employment to majority of the people. Horticultural sector is defined as the growing of fruits, vegetables and ornamental plants (Tindal, 1987). In Tanzania, fruits and vegetables are the main horticultural crops produced predominantly by small-scale farmers located in different agro ecological zones, which support a variety of products (Kusolwa, 2003).

Mango, citrus, papaya, passion, guava, avocado, cucumber and water melon are among the horticultural crops grown by small-scale farmers for domestic urban markets and exports to major outlets in Europe and Middle East (Ekesi *et al.*, 2006). Furthermore, water melon is grown by many farmers due to its importance not only as a fruit vegetable but also as source of income. The fruit supplies essential nutritional materials which may not be readily available from other sources (Tindal, 1992).

In Tanzania, water melon is mostly grown in Morogoro, Dar-Es-Salaam, Coast, Tanga, Mtwara, Lindi and other Regions with favourable environmental conditions (Rice *et al.*, 1987). The production of Water melon crop by small-scale farmers in Tanzania is greatly hampered by many factors including edaphic factors, poor field management practices at all levels, post harvesting handling, and infestation by insect pests.

Generally, water melon yields in Tanzania are very low and this could be attributed to many factors including pests, notably fruit flies. True fruit flies (Diptera: Tephritidae) include some of the world’s most serious agricultural pests having a severe economic impact on tropical and subtropical agriculture in many parts of the world including Tanzania. Fruit flies pose an increased threat of spreading to new areas (White and Elson-Harris, 1992). The melon fly *B. cucurbitae* (Coquillet) is one of the most serious insect pests of cucurbit species. This pest has been reared from over 125 fruit species mainly of the family Cucurbitaceae (Mumford, 2004; Allwood *et al.*, 1999). The pests cause enormous losses which include direct damage to fruits, damage of succulent tap roots, seedlings and stems resulting into loss of markets.

1.2 Justification of the Study

Water melon (*Citrullus lanatus*) (Thunb.) Matsumara and Nakai is among the major fruit vegetables grown by farmers in Tanzania. The fruit is a major source of income especially to smallholder farmers. In recent years the production of the crop has declined due to insect infestation including, melon flies *B. cucurbitae*. The decline in production of water melons has had serious consequences on the livelihoods of many farmers who depend on water melon production for income generation. Identifying which factor is responsible for the decline in yield of the watermelon will help in developing better management strategies that will eventually improve/ increase production. Also identifying plant species used as roosting site responsible for controlling *B. cucurbitae* and baits that will be locally available it reduces cost of production and increase income of house hold.

The use of botanicals has many advantages including less health hazards, being environmentally friends, low cost of production and it facilitates international trade. (Grange and Ahmed, 1988). Therefore, there is a need to explore the potential of botanicals in controlling *B. cucurbitae*, and developing an integrated control strategy for effective management that will be useful to farmers.

According to Dhillon *et al*. (2005) the infestation rates due to fruit flies vary among countries and seasons ranging from 5% to 100%, and that the extent of losses varies between 30 to 100%, depending on the cucurbit species and the season (Singh *et al*., 2000). The damage caused by *B. cucurbitae* may be as high as 31.27% on bitter gourd and 28.55% on Water melon (Singh *et al*., 2000).

Several methods for management of *B. cucurbitae* have been recommended. These include; quarantine regulations by imposing restrictions on the importation of variety ie of cucurbits to the importing countries and prevention of the establishment of new pests (Lux *et al.,* 2003). The use of synthetic insecticides and toxic food bait sprays to suppress *B. cucurbitae* populations has been tried but these are expensive and mostly inaccessible to resource poor farmers.

There is a need, therefore, to test locally formulated baits on their efficacy in reducing crop losses as well as the costs of controlling *B. cucurbitae*. Also there is a need to determine the effectiveness of such baits in trapping *B. cucurbitae* in order to develop an integrated control strategy for effective management of *B. cucurbitae* useful to farmers. The aim of this study is to investigate ways of reducing losses of water melon due to infestation by *B. cucurbitae* through the use of locally formulated baits. The findings are expected to help small scale farmers reduce cost and losses due to *B. cucurbitae* in Tanzania.

1.3 Objectives

1.3.1 Overall objectives

To evaluate effectiveness of locally available materials in managing the melon fly, *B. cucurbitae*.

1.3.2 Specific objectives

i. To determine the efficacy of *D. elliptica* as toxicant for *B. cucurbitae*.

ii. To determine the efficacy of molasses based bait in managing *B. cucurbitae*.

iii. To determine the efficacy of brewer's waste based bait in monitoring *B. cucurbitae* populations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Water melon *Citrullus lanatus* (Thunb.) Matsumara and Nakai

2.1.1 Description of the crop

Water melon is an annual vine like climber and trailer crop, belonging to the family *Cucurbitaceae* of the order Cucurbitales. Its fruit has a green or yellow thick rind and a fleshy center. Water melon fruit weighs between 2 to 18 kg when matured. The leaves are deeply lobed and dark grayish-green in color. It is a monoecious plant whose roots are extensive and superficial while stems are thin, angular, grooved and reach 1.5-5m in length, with long white hairs. Although it is native to Central Africa, the watermelon was first grown by ancient Egypt as well as India and China (Tindal, 1992).

2.1.2 Importance of Water melon

Economic importance

Water melons are among the major vegetables fruits grown by farmers in Tanzania. It is a source of income especially to smallholder farmers. The increasing populations of many tropical countries have led to a new awareness of the importance of fruit vegetable crops as a source of income and food (Tindal, 1992). Fruits and vegetables grown for domestic urban markets have great export potential to major outlets in Europe and the Middle East (Ekesi *et al.*, 2006).

Nutritional importance

According to Tindal (1992), the fruits are generally eaten row rather than cooked and the seeds are sometimes ground to make flour which may be added onto the food as cooking oil. The young leaves are cooked or added to soups. The nutrient content of water melon is shown in Table 1.

Table 1: Nutrient content of water melon (100g of edible portion)

Nutrients	Content
Water	93 mil
Calories	22kcal
Protein	0.5 kcal
Fat	0.1 kcal
CHO	5 kcal
Fibre	0. 4 kcal
Calcium	8mg
Phosphorus	9mg
Iron	0.3mg
(vitamins)=better carotene equiv.	250 *u g*
Thiamine	0.04mg
Riboflavin	0.05mg
Niacin	0.1 mg
Ascorbic acid	15mg.

Source: Tindal (1992)

2.1.3 Production of water melon in Tanzania

In Tanzania watermelons are mainly produced by smallholder farmers and few commercial farmers for export. The increasing populations of many tropical countries have led to a new awareness of the importance of fruit vegetable crops as sources of income, food and vitamins accompanied by the realization that many fruits can supply essential nutritional materials which may not be readily available from other sources (Tindal, 1992). In 2003 Tanzania produced 539 tonnes/ ha, of watermelon compared to Kenya's 619 tonnes/ha, as indicated in Table 2 below.

Table 2: Water melon production in East Africa (x100 tonnes)

Country	Year			
	2002	**2003**	**2004**	**2005**
Djibouti	0.06	0.06	0.05	0.05
Kenya	4.88	6.19	6	6.07

Tanzania	0	5.39	0	0
Uganda	0	0	0	0

Source: FAO (2005)

2.1.4 Factor affecting production of water melon

The production of water melon is constrained by several factors including infestation by insect pests, poor field management practices at all levels, poor post harvest handling, high costs of pesticides, perishability due to its high water content and lack of good storage facilities. A number of fruit fly species attack water melons, these include; melon fly, *B. cucurbitae* (Coquillett), peach fruit fly, *B. zonata* (Saunders), lesser pumpkin fly, *Dacus ciliatus* (Loew), *D. punctatifrons* (Karsch), jointed pumpkin fly *D. vertebratus* (Bezzi), African invader fly, *B. invadens* Drew, Tsuruta & White and Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann). Among these, the losses due to *B. cucurbitae* are undoubtedly very high (CABI, 2005).

2.2 The Melon Fly, *Bactrocera cucurbitae* (Coquillett) (Diptera:Tephritidae)

2.2.1 Description

The distinctive features of *B. cucurbitae* include a yellow stripe in the middle of the thorax between the wings, a black (often incomplete) T-shaped marking on the abdomen (the rear body section) and additional dark patches towards the outer edge of the wings (Dhillon *et al.*, 2005). Wing pattern is the easiest and the most distinguishing characteristic because the general colour of *B. cucurbitae* is inconsistent and therefore unreliable (Fig.1).

Figure 1: Distinctive feature of female *B. cucurbitae*

2.2.2 Biology and Ecology

Female flies start laying eggs 11-12 days after their emergence from pupae. A female inserts eggs under the skin of fruits using its sharp ovipositor, and can infest a wide range of fruits. Eggs are laid in batches of 1-40 in young to ripe fruits, but also on flowers, buds and even leaf stalks and stems of host cucurbits (Weems and Heppner, 2001). One female may lie over 1000 eggs during her life. Oviposition peaks occur in the morning and late afternoon. The life cycle of *B. cucurbitae* from egg to adulthood takes 14-27 days (White and Elson-Harris, 1992) as the development depends on temperature. Optimum rate of growth occurs at 77˚F (25˚C) and 50% relative humidity. Cool temperatures slow down the development cycle of *B. cucurbitae* while warmer temperatures speed up the development of the species.

The eggs of *B. cucurbitae* are white and may be up to 0.16cm long; the larvae range from 0.16cm- 0.95cm in length. Just before pupating, the larvae often pop and flip to leave the fruit. Pupation normally occurs 1-2 inches deep under the soil. Doharey (1983) observed that the pupal period lasts for 7 days on bitter gourd and 7.2 days on pumpkin and squash gourds at 27 ± 1° C. Depending on the temperature and the host, the pupal period may vary from 7 to 13 days (Hollingsworth *et al*., 1997). On different hosts, the pupal period varies from 7.7 to 9.4 days on bitter gourd, cucumber and sponge gourd and 6.5 to 21.8 days on bottle gourd (Koul and Bhagat, 1994; Khan *et al*., 1993). Adults usually rest in shady locations except when feeding, mating or laying eggs. Ovipositor (egg-laying tube) has a plump, straight sheath (the outer cover of the ovipositor) and is about 0.16cm long. Most of the feeding of this insect pest takes place at down and mating at dusk (White and Elson-Harris, 1992).

2.2.3 Host range of *B. cucurbitae*

According to (Dhillon *et al.*, 2005), *B. cucurbitae* has more than 120 hosts. It is a major pest of watermelon (*C. lanatus*), cucumber (*Cucumis sativus* L.), beans (*Vigna unguiculata* and *Phaseolus vulgaris* L.), bitter gourd (*Momordica charatia* L.), Chinese wax gourd (*Benincasa hispida* Thunb.), edible gourds (*Cucurbita maxima* L.) and eggplant (*Solanum melongenna* L.). Others include; luffa (*Luffa acutangula* Mill.), melons (*Cucumis melo* L.), pepper (*Capsicum frutescens* L.), pumpkin (*Cucurbita pepo* L.), tomato (*Lycopersicon esculentum* Mill.), papaya (*Carica papaya* L.) and zucchini (*Cucurbita pepo* L.). According to Doharey (1983*)*, *B. cucurbitae* infests over 70 host plants, amongst these include fruits of bitter gourd (*Momordica charantia*), muskmelon (*Cucumis melo*), snap melon (*Cucumis melo var. momordica*) and snake gourd (*Trichosanthes anguina* and *T. cucumeria*). These are the most preferred hosts. However, White and Elson-Harris (1992) stated that many of the host records might be based on casual observations of adults resting on plants or caught in traps set in non-host plant species. Based on an extensive survey carried out in Asia and Hawaii, *B. cucurbitae* damage over 81 host plant species which belong to the family cucurbitaceae (Allwood *et al.*, 1999).

2.2.4 Distribution of *B. cucurbitae*

The pest is distributed widely in temperate, tropical, and sub-tropical regions of the world. It is widely distributed in India, which is considered its native home, and throughout most of southeastern Asia. Other populations have been reported in Africa (Egypt, Benin, Ghana, Cameroon Kenya and Tanzania), Burma, Ceylon, China, Guam, Hawaii, New Guinea, Rota, Commonwealth of the Northern Marianas, Southeast Asia and Asia (White and Elson-Harris 1992; Dhillon *et al.*, 2005).

2.2.5 Economic importance of *B. cucurbitae*

The economic importance cannot be evaluated entirely from the standpoint of the direct damage to the various crops affected, but it can be ranked as the most serious pests of water melon (White and Elson-Harris, 1992). Quarantine laws, aimed at preventing the entry and establishment of *B. cucurbitae* in areas where it does not occur are often used to increase the export potential of locally grown crops. Singh *et al*. (2000) and Dhillon *et al*. (2005) reported that, the damage caused by *B. cucurbitae* in India amounted to 31.27% on bitter gourd and 28.55% on watermelon. Further more *B. cucurbitae* has been reported to infest 95% of bitter gourd fruits in New Guinea and 90% of snake gourd and 60 to 87% of pumpkin fruits in Solomon Islands (Hollingsworth *et al*., 1997). For cucurbitaceous crops, *B. cucurbitae* damage is the major limiting factor in obtaining good quality fruits and high yield (Rabindranath and Pillai, 1986).

The extent of losses varies between 30 to 100%, depending on the cucurbit species and the season. There is no reliable data from Tanzania. Species abundance increases when the temperatures fall below 32° C, and the relative humidity ranges between 60 to 70%. It prefers to infest young, green, soft-skinned fruits. As Weems and Heppner (2001) reported, the damage to crops caused by *B. cucurbitae* resulting from oviposition in fruit and soft tissues of vegetative parts of hosts leads to the decomposition of plant tissue by invading secondary microorganisms. All these reduce the market value of the produce.

2.2.6 Management of *B. cucurbitae* under local area management

The fruits of cucurbits, to which the *B. cucurbitae* is a serious pest, are picked up at short intervals for marketing and self-consumption. Therefore, it is difficult to rely on insecticides as a means of controlling this pest. In situations where chemical control of

B. cucurbitae becomes necessary, one has to rely on soft insecticides with low residual toxicity and short waiting periods. Keeping in view the importance of the pest and crop, *B. cucurbitae* management could be done using local area management (Dhillon *et al.*, 2005). Local area management is the minimum scale of pest management over a restricted area and which aims at suppressing the pest, rather than eradicating it. A number of methods can be employed to keep the pest population below economic threshold in a particular crop over a period of time to avoid the crop losses. This can be done with less health and environmental hazards which is the immediate concern of the farmers. The methods include f*ield sanitation, monitoring and control with parapheromones, biological control, host plant resistance and chemical control* (Dhillon *et al.*, 2005).

Field sanitation

The most effective method in *B. cucurbitae* management is primary component- field sanitation. To break the reproduction cycle and population increase, growers need to remove all unharvested fruits or vegetables, unmarketable and infested fruits and dispose all residues immediately after harvest by completely burying them deep into the soil. Burying infested and damaged fruits 0.46 m deep in the soil prevents adult fly eclosion and reduces population increase. Addition of lime is helpful to kill emerging larvae (Klungness *et al.*, 2005).

Host plant resistance

Host plant resistance is an important component in integrated pest management programs. It does not cause any adverse effects to the environment, and no extra cost is incurred to the farmers. Unfortunately, the success in developing high yielding and fruit fly-resistant varieties has been limited. There is a distinct possibility of transferring resistance genes in the cultivated genotypes from the wild relatives of cucurbits for developing varieties resistant to *B. cucurbitae* through wide hybridization (Dhillon *et al*., 2005).

Chemical Control

The control of *B. cucurbitae* using chemicals is relatively ineffective. However, insecticides such as malathion, dichlorvos, phosphamidon, and endosulfan are moderately effective against the melon fly (Agarwal *et al*., 1987). According to Bhatnagar and Yadava (1992) malathion (0.5%) tend to be more effective than carbaryl (0.2%) and quinalphos (0.2%) on bottle gourd, sponge gourd, and ridge gourd. The application of molasses plus malathion (Limithion 50 EC) and water in the ratio of 1: 0.1: 100 provides good control of *B. cucurbitae* (Akhtaruzzaman *et al*., 2000). The application of either 0.05% fenitrothion or 0.1% carbaryl at 50% appearance of male flowers, and again at 3 days after fertilization is helpful in reducing *B. cucurbitae* damage (Srinivasan, 1991). Gupta and Verma (1982) reported that fenitrothion (0.025%) in combination with protein hydrolysate (0.25%) reduced *B. cucurbitae* damage to 8.7 % as compared to 43.3 % damage in untreated control.

Vargas *et al.* (2003) demonstrated that two closely related species, *B. dorsalis* and *B. cucurbitae,* can have significant differences in response to protein baits. The implication of this on integrated pest management shows that the use of insecticidal protein bait such as GF-120 (spinosad) is likely to be much more effective at controlling *B. cucurbitae* than is the *B. dorsalis* because these baits are more attractive to the former than to the latter. However, once both species arrive at the insecticidal baits, the outcome is likely to be the same with almost all flies dying within 24 hrs. Klungness *et al.* (2005) studies reveal that, the three techniques namely sanitation, male annihilation and GF120 (spinosad), were able to reduce the *B. cucurbitae* population from the grid traps deployed at 1 trap per Km^2.

Observations by Prokopy *et al*. (2003) in Hawaii show suppression activities which were implemented on a few large farms, reduced infestation of *B. cucurbitae* to 5% on farms compared to 30% before the program.

2.2.7 Management of *B. cucurbitae* under Area- wide management

The methods used for a wide area management approach include male-sterile insect release, insect transgenesis, biological control and quarantine control techniques in combination with available local area management options. The aim of a wide area management is to coordinate and combine different characteristics of an insect eradication program over an entire area within a defensible perimeter. The area must be subsequently protected against reinvasion by quarantine controls, for example, by pest eradication on isolated islands (Dhillon *et al.*, 2005).

Quarantine

The import and export of infested plant material from one area or country to other non-infested places is the major mode of the spread of insect-pests. The spread of *B. cucurbitae* can be blocked through tight quarantine and treatment of fruits at the import/export entry ports. For example, cold treatment at 1.1 ± 0.6° C for 12 days can disinfest Hawaiian star fruit, *Averrhoa carambola*, of tephritid eggs and larvae (Armstrong *et al.*, 1995). Heat treatment of avocado fruits infested with eggs and larvae of *B. cucurbitae* at 40° C for 24hours reduce the estimated surviving population by 99.5 to 100%.

Suppression Techniques

Techniques for the suppression of *B. cucurbitae* have recently been reviewed by Dhillon *et al*. (2005). These authors emphasized the need for an integrated approach to *B. cucurbitae* management. Early efforts to control *B. cucurbitae* in Hawaii revolved around the work of Nishida and Bess (1950), Nishida *et al*. (1957) and Nishida (1954), from which the concept of spraying bait (protein hydrolysate) on border vegetation was developed. Okinawa Prefecture in Japan had eradicated *B. cucurbitae* using a combination of techniques which included aerial broadcasting of blocks treated with cue lure and organophosphate pesticide and the release of sterile fruit flies (Koyama *et al*., 2004). Their successes have supported all other programs in the world, but were accomplished at great expense on the part of the government and with demands on the people and the environment that would be unlikely to be tolerated in the State of Hawaii.

The country of Nauru undertook the eradication of all fruit fly species on their island including *B. cucurbitae*. As with the aforementioned programs, this always includes the use of a toxicant with cuelure and/or methyl eugenol. Usually, the toxicant was malathion or dibrom used both in the lure traps (usually fiber blocks or coconut husk) and in bait sprays applied directly to the vegetation. GF-120 (spinosad) is being adopted in the United States because it has low mammalian toxicity, and has passed stringent tests of its impact on beneficial insects and aquatic organisms. It has also been shown to be highly effective against starved *B. cucurbitae* (Prokopy *et al*., 2003, 2004).

Biological control

There are no reports on the successful use of bio-control agents against *B. cucurbitae*. Srinivasan (1994) reported *Opius flatcheri* Silv. to be a dominant parasitoid of *B. cucurbitae*, but the efficacy of this parasitoid has not been tested under field conditions in India. The parasitization of *B. cucurbitae* by *O. flatcheri* has been reported to vary from 0.2 to 1.9% in *Mommodica charantia* fields in Honolulu Hawaii (Wong *et al.*, 1989). More recently, a new parasitoid, *Fopius arisanus* has also been included in the IPM program of

B. cucurbitae at Hawaii (Wood, 2001). The fungus, *Gliocladium virens* Origen, has been reported to be effective against *B. cucurbitae* (Sinha and Saxena, 1998). Culture filtrates of the fungi *Rhizoctonia solani* and *Trichoderma viridae* Pers., affected the oviposition and development of *B. cucurbitae* adversely (Sinha and Saxena, 1999).

Thirty-two species and varieties of natural enemies to fruit flies were introduced to Hawaii between 1947 and 1952 to control the fruit flies. These parasites lay their eggs in the eggs or maggots and emerge in the pupal stage. Only three, *O. longicaudatus* var. *malaiaensis* (Fullaway), *O. vandenboschi* (Fullaway), and *O. oophilus* (Fullaway), have become abundantly established. These parasitoids are primarily effective on the oriental and Mediterranean fruit flies in cultivated crops. The most efficacious parasite of *B. cucurbitae* is *O. flatcheri* (Silvestri) which was introduced in 1916 from India. This parasite attacks *B. cucurbitae* during the larval stage. Bess *et al*. (1961) reported that this parasite killed 20-40 percent of fruit fly larvae. It is more effective in reducing populations in wild areas than in cultivated crops.

2.3 Current Practices in the Management of *B. cucurbitae*

The current trend of the management of *B. cucurbitae* involves the use of bait sprayed on border crop and population monitoring.

2.3.1 Monitoring of *B. cucurbitae* population

The purpose of monitoring is to identify fruit fly pest in an area, to determine the distribution of pest species, to identify local host spots with high populations of pest, to track changes in population levels, to determine efficacy of control measures and to facilitate early detection of new fruit fly pests in a particular area. According to Cunningham (1989), Heath *et al*. (1997) and Lux *et al*. (2003), there are two types of attractants used in monitoring namely para-pheremones of male lure and food baits. Food baits which are available in both liquid and dry synthetic forms can also attract a number of non-target insects, including beneficial ones. Ammonia is the principal attractant emanating from food baits. There are varieties of commercially available food baits, these include liquid protein hydrolysates, yeast products, ammonium salts and the three-component lure (consisting of putrescine, ammonium acetate and trimethylamine). Mazor *et al.* (1987), Heath *et al.* (1997), Lux *et al*. (2003) and IAEA (2003). Field longevity of protein hydrolysates, yeast products and ammonium salts are usually between 1-2 weeks while the three-component lure can last between 4-6 weeks. The minimum distance interval between foods baited traps ranges from 10-30m. Fig. 2 shows the overview of monitoring of fly species by McPhail trap. Gopaul and Prince (1999) observed that commercial protein baits and locally made brewers yeast are widely used in fruit fly managements, in traps for monitoring and sport spray for control and also locally produced brewers waste prepared from tusker brewery liquid appeared to attracts large number of *B. cucurbitae* as the commercial protein hydrolysate.

Figure 2: Monitoring of *B. cucurbitae* by McPhail trap on water melon field

2.3.2 Use of baits spray on border crops

According to McQuate and Vargas (2006), effectiveness of bait sprays for suppression of tephritid *B. cucurbitae* populations requires that they be applied in areas where the flies feed. It is standard practice to apply bait sprays to plants bordering a host crop area, and not to the host crop itself, for the suppression of *B. cucurbitae* populations. In contrast, bait spray applications for suppression of oriental fruit fly, *B. dorsalis* (Hendel), and populations have traditionally applied to the host crop, rather than to crop borders. Thus, *B. cucurbitae* can also be controlled through the use of *Ocimum sanctum* as the border crop sprayed with protein bait (protein derived from corn, wheat or other sources) containing spinosad as a toxicant (Roomi *et al.*, 1993).

Agarwal *et al*. (1987) reported that, the chemicals used for *B. cucurbitae* control have been used as toxicants in baits applied to refugia of the fruit flies and sprays applied to the crop. Proteinaceous liquid attractants in insecticide sprays is a recommended method of controlling adult *B. cucurbitae* populations in the vicinity of crops. The bait insecticide sprays are applied to broad leaf plants that serve as refugia for *B. cucurbitae* adults. Baits serve to encourage the adults to feed on the spray residue and can provide good rates of kill. To be effective, bait-insecticide sprays must be used in combination with good sanitation practices. These practices include destruction of unmarketable fruit on every harvest date, and destruction of crop residues immediately after economic harvest has been completed. There is potential of using botanical toxicants mixed with food baits in managing *B. cucurbitae.* Such toxicants include *D. elliptica*.

2.3.3 Derris plant, *Derris elliptica* (Roxb)

Derris is a small shrub which belongs to the Leguminoceae family (Stoll, 1987) (Fig. 3). This plant originated in tropical rain forests of the Malay Archipelago. In general, *D. elliptica* thrives in lowland areas. However, in Tanzania *D. elliptica grows* in the highlands of Amani and Magoroto Palm estate in Muheza district in Tanga region. There are three known species of *Derris*. These are *D. ellipica, D. malaccensis and D. uliginosa* (Stoll, 1988). Only *D. elliptica* is found in Tanzania. The roots of Derris contain the active substances for stomach, contact poisons and repellant. The most important active compound is rotenone (Brein, 1969; Ramulu, 1985; Stoll, 1987, 1995). The production of active compounds from Derris depends on some environmental and soil factors. *D. elliptica* grows well in many types of soils but mostly on loam and clay soils. It can be propagated vegetatively using cuttings of 50-cm length. After planting, the development of roots can take six weeks (Stoll, 1988). *D. elliptica* is ready for harvesting from 18 to 27 months after planting and can produce 454.5 to 2045.5 kg of dry roots per hectare if trailing system is followed (Ramulu, 1985).

Figure 3: Photo of Derris plant (*Derris elliptica*)

2.4 Potential Uses of Locally Formulated Baits in Managing and Monitoring of *B. cucurbitae*

According to Roy *et al*. (2005), the use of locally available medicinal plants in the control of pests is an ancient technology in many parts of the world. Most of these botanical pesticides are non-selective poisons that target a broad range of pests. It maintains biological diversity of predators (Grange and Ahmed, 1988), and reduces environmental contamination and human health hazards. Botanical pesticides are unique because they can be produced easily by farmers and small industries (Roy *et al*. 2005). However, *D. elliptica* plants are cheap as they are locally available but should be used with care because of stomach and contact poison, insecticidal and repellents (Stoll, 1987). As consumer demand for organically produced foods increase, scientific research on the use of botanical pesticides is now gaining momentum (Nas, 2004).

Knowledge gap observed in this study is that, work using locally produced baits in the control of *B. cucurbitae* is shortly to be conducted in Tanzania. However, the knowledge of how such mixtures work, in particular the components and mechanisms involved in the attraction of fruit flies to bait is still poor.

2.5 Use of Molasses in the Managements of *B. cucurbita*e

In the first half of the century baits mixtures of carbohydrates and other fermenting substances such as molasses and sugars in combination with inorganic insecticides such as lead arsenate were used (Roessler, 1989). The research results demonstrate the potential of locally produced bait as a cheaper alternative in *B. cucurbita*e control. Both preparations attracted significantly more fruit flies than the water controls. In general there were no significant differences between the locally produced bait formulations and the imported bait in numbers of fruit flies trapped. These results demonstrate the potential of locally produced baits as cheaper alternative in fruit fly control.

CHAPTER THREE

3.0 MATERIALS AND METHODS

Three experiments to determine losses and evaluate effectiveness of locally formulated baits in managing *B. cucubitae* were conducted from August 2008 to June 2009 in Morogoro region. The study was conducted in three sites of Sokoine University of Agriculture (SUA) Horticulture Unit, Mazimbu Horticulture Unit and Tobacco processing industry garden. All the sites are in the medium altitude agro-ecological zone.

3.1 Determining the Efficacy of *D. elliptica* as Toxicant for *B. cucurbitae*

3.1.1 Preparations of crude extracts of *D. elliptica*

The roots of *D. elliptica* were collected from Tanga, Muheza district. These were sun dried for five days and then placed in a cool, dark place to avoid thermol and photo-decomposition of the active ingredients (Stoll, 1987, 1988, 1995), (Fig. 4). The dried roots were ground into powder and soaked in clean water for twelve hours to allow the active ingredient to dissolve in water (Stoll, 1988).

Figure 4: Photo of dried roots of *Derris elliptica*

3.1.2 Establishing *B. cucurbitae* population

Cucurbit fruits were collected from within agro ecological zone of Morogoro Region. The fruits were transported to the rearing unit established at Sokoine University of Agriculture (SUA) and placed in rearing cages. Each rearing cage constituted a container which was perforated with ellipsoid holes at the bottom with polythene mesh-covered top for ventilation. This was tightly fitted on top of a second container with thin a layer (one cm) of moistened sterile sand soil to hold exudates dripping from the rotting fruits. The sand soil served as pupation substrate for the popping larvae as they left the fruits. The ellipsoid holes prevented the fruits from clogging the holes and allowed mature larvae to fall into the soil after leaving the host fruit.

The rearing of fruit flies followed the procedures outlined by the African Fruit Fly Initiative (AFFI) (Ekesi, 2006). Two weeks after initiating rearing, fruits were examined daily for the emerging fruit flies. This was continued until no more flies were observed (25 – 30 days after initiation of incubation).

The fruits flies that emerged were removed from rearing cages by an aspirator (pooter) and placed in plastic rearing cages covered with polythene mesh on top with round opening aside fitted with a sleeve, which could be folded to close the opening. Adult fruit flies (*B. cucurbitae)* were fed water and a diet consisting of one part of protein baits and three parts of sugar (Fig. 5).

Figure 5: A photo of modified fruit fly plastic rearing cages

3.1.3 Determining lethal dose for *B. cucurbitae*

Two different experiments were carried out under laboratory condition in Completed Randomize Design (RCD). One of the experiments involves testing *D. elliptica* (poison) mixed with protein bait and the other one involved testing *D. elliptica* (poison) mixed with molasses and water against adult of *B. cucurbitae* at different concentrations. An assay was designed to determine the quantity of *D. elliptica* (poison) that could kill more than 50% of flies in the cages.

Concentrations of extracts from *D. elliptica* were prepared by mixing 0 g, 0.5 g, 1.0 g, 1.5 g 2.0 g, and 2.5 g (treatments) each added with 16 g of protein baits in the Petri dishes. The same concentration of botanical powder *(D. elliptica)* (0 g, 0.5 g, 1.0 g, 1.5 g 2.0 g, and 2.5 g) each was mixed with 100ml of molasses and 1litre of water, (all these were replicated five times). Each concentration was placed in a plastic cage and assigned randomly. 20 live adult *B. cucurbitae* flies were placed in each container and left to feed after being starved for 12hrs.

Mortality responses were observed after 12hrs, 24hrs, and 36hrs respectively. The control consisted of flies feeding on protein baits and/ or molasses with no poison added. No fresh diet replacements were made d at a certain time.

Dead flies were counted and percentage mortality was determined and recorded. The recorded percentage mortality was then transformed into probits which were read from the probit transformation table (Busvine, 1971). Then lethal doses of botanical extracts were determined by probit analysis after being exposed to different concentrations after 12, 24 and 36 hrs, in five replicates. Analysis of Variance (ANOVA) was used to determine effect of time of exposure and concentration on mortality to respective hours. The data were analyzed using GenStat Discovery Edition 3.

3.2 Determining the Efficacy of Molasses Based Bait in Managing *B. cucurbitae*

3.2.1 Field experiment

The study was conducted in three locations; Sokoine University of Agriculture (SUA) Horticulture Unit (S06˚ 56′ 04.0″, E037˚ 32′ 50.8″ and 515 m a.s.l.); Mazimbu Horticulture Unit (S06˚ 47′ 39.9″, E037˚ 38′ 04.9″ and 490 m a.s.l) and Tobacco processing industry garden at S06° 48' 47.5" E037° 39' 01.8" 525 m a.s.l. All the sites are in the medium altitude agro-ecological zone of Morogoro Region.

3.2.2 Crop establishment

Experimental plots were prepared following standard agronomic procedures. Watermelon seeds were sown direct (in situ). The total experimental area in each location was 900m^2. Spacing between plants was 1.5 m X 1.5 m. Roosting host plant herein maize was planted four weeks before transplanting of seedlings. Irrigation water and other agronomical practices were applied during the cropping season.

3.2.3 Design of experiment

Completely Randomized Block Design (CRBD) in three locations was used. The treatments were no-spray (T1), molasses and botanical extract sprayed on border crop (T2), pesticide (Dimethoate 40EC) sprayed on crop (T3) and GF-20 (spinosad) sprayed on border crop (T4). Each treatment was applied on an individual plot measuring 100m². Four weeks after sowing, (starting of flowering) baits were sprayed on the roosting host plant while an insecticide was sprayed on the crop. The doses were as follows;

Molasses mixed with *D. elliptica* was applied on the border crop at the rate of 1littre of molasses mixed with 400 g of *D. elliptica* extract in 20 litres of water. Dimethoate 40 EC was applied on the crops at the rate of 30 mls in 20 litres of water GF-120 (containing 0.02 spinosad) was applied on the border crop at the rate of 1litre GF-120 in 40 litres of water

A spraying was done once per week and this was done for three weeks. One week after the end of the last spray, all the crops were harvested separately as per assigned treatments and procedure. At that time, the crop was 40 days old from the date of sowing (*B. cucurbitae* attack fruits at a very early stage). Crop residues were harvested and completely buried in the soil. The procedure was repeated three times at all three locations with treatments randomly assigned. The three locations were the blocks and the three cropping are the replications. Fruits obtained from each plot were transported to the fruit fly rearing unit established at SUA Horticulture Unit where they were reared using the method described by Copeland *et al*. (2002).

The data that were recorded include the number of fruits, the weight of fruits and the number of emerged individuals of fruit fly species.

3.4 Determining the Efficacy of Molasses, Brewer's Waste Bait in Monitoring *B. cucurbitae* populations

3.4.1 Efficacy of monitoring baits

The efficacies of locally formulated baits in monitoring the population of the *B. cucurbitae* were tested in Randomized Block Design (RBD) at Sokoine University of Agriculture (SUA) Horticulture Unit. Four plots of watermelon crop measuring 100m^2 were established, the distance from one plot to another was 50m. The crops were unsprayed and McPhail traps containing baits were hung on a wooden pole 1.5m above the ground. Differently prepared bait solution were added with water to each trap in the following concentration; protein baits 20 g, solulys 20 g, brewers waste (dried) 20 g, and molasses 15 mls to come up with 200 mls each. Brewer's wastes were obtained from Dar Es Salaam Ilala breweries. Brewer's waste was sun dried and ground. Re- baiting was done every week by pouring new baits carefully without any spillage on the external surface of the trap body. The liquid food bait was poured into container through a sieve to recover the trapped insects by using fine brush and soft forceps. The trapped fruit flies were stored in the prepared vials ready for counting and identification according to species and sex. The traps were randomly placed after each servicing. The process was repeated for 8 weeks. Food baits were replaced every week. Trap catches were recorded in terms of number of flies per trap per week.

One-way Analysis of Variance (ANOVA) was used to determine the difference between baits used, i.e. trap catches (the number of flies per trap per week)**.** Kruskal-wallis a non parametric test was used to compare and contrast effectiveness of baits in attracting flies.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Efficacy of *D. elliptica* and Molasses Bait in Management of *B. cucurbitae*

The toxicity of *D. elliptica* mixed in molasses was evaluated in a laboratory bioassay. The results demonstrated susceptibility of *B. cucurbitae* to *D. elliptica* at different levels of concentration and time of exposure. High mortality of *B. cucurbitae* was observed as the concentration of *D. elliptica* increased from 1.5 g/l to 2.5g/l at 24 and 36 hours. The mortality of *B. cucurbitae* was higher at high concentrations and longer periods of exposure than at low concentrations and short periods of exposure. The results show significant difference (LSD, 0.0233, df = 2; P<0.05) in mortality of *B. cucurbitae* at different times of exposure to *D. elliptica* in molasses baits (Fig. 6).

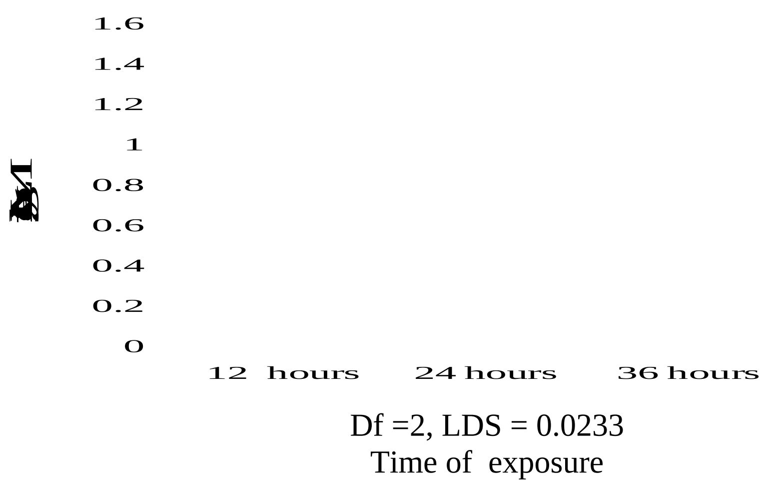


Figure 6: Mortality of *B. cucurbitae* after being treated with *D. elliptica* with molasses at different times

The results also show significant difference (LSD, 0.04893, df = 5; P< 0.05) in mortality of *B. cucurbitae* between concentration levels of *D. elliptica* in molasses baits (Fig. 7).

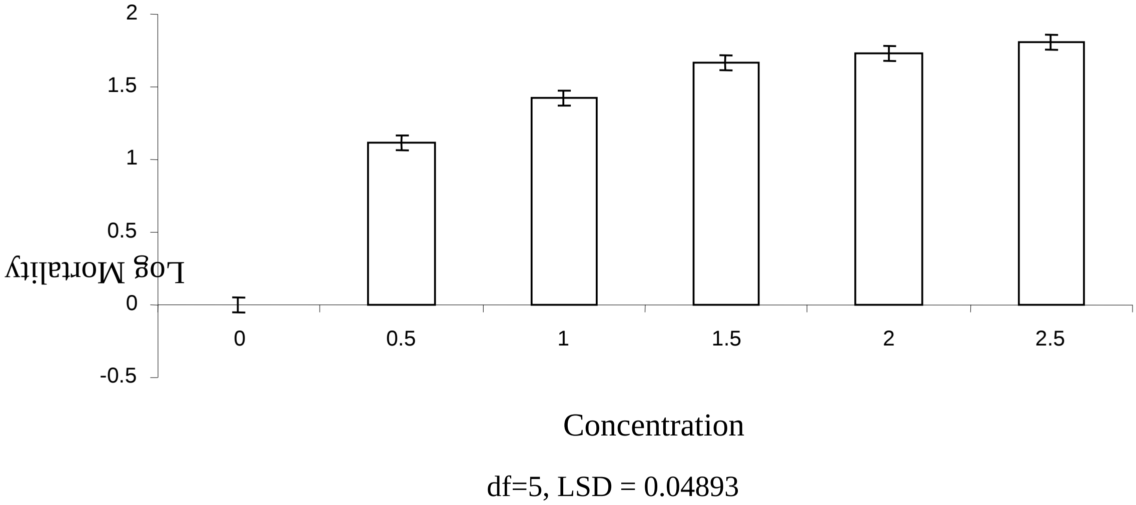


Figure 7: Mortality of *B. cucurbitae* after being treated with *D. elliptica* mixed with molasses at different concentrations

The overall results observed could be due to the fact that mortality increases as the concentration and time of exposure to poison increases. Similar results were reported by Ng'homa (1999) who observed that, mortality of Aphids, *Aphis gossypii* (Glover) increased with the concentration of *D. elliptica* and time of exposure.

The results further show significant difference (LSD, 0.07981, df = 10; P< 0.05) in mortality of *B. cucurbitae* between different concentration levels and time of exposure to *D. elliptica* in molasses baits (Fig. 8).

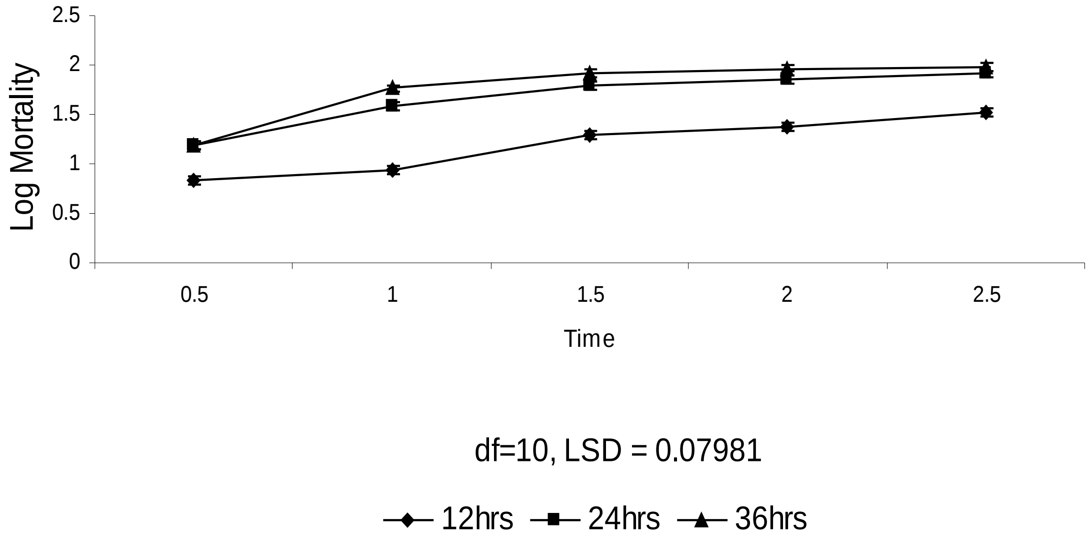


Figure 8: Mortality of *B. cucurbitae* after being treated with *D. elliptica* mixed with molasses at different times versus concentrations

4.2 Efficacy of *D. elliptica* mixed with Brewer's Yeast Baits in Management of *B. cucurbitae*

Toxicity of *D. elliptica* mixed with brewers yeast bait to *B. cucurbitae* was evaluated in a laboratory bioassay. High mortality of *B. cucurbitae* was observed as the concentration of *D. elliptica* increased from 1.5 g/l to 2.5 g/l in brewers yeast bait at 24 and 36 hours. Adult mortalities were increased not only by *D. elliptica* concentrations but also by increasing the time of exposure.

The results show significant difference (LSD, 0.14, df = 2; $P<0.05$) in mortality of *B. cucurbitae* at different times of exposure to *D. elliptica* in brewer's yeast bait (Fig. 9).

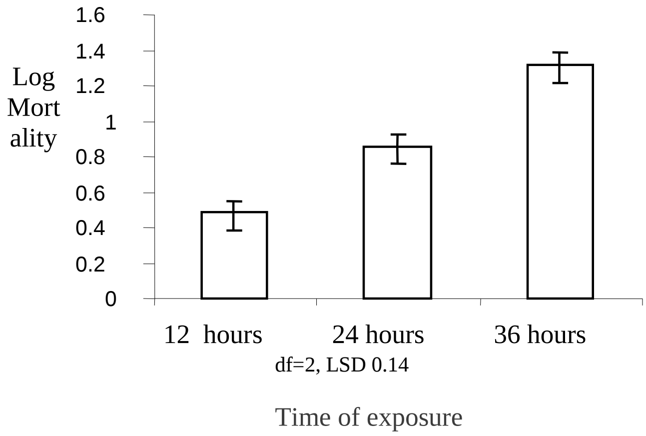


Figure 9: Mortality of *B. cucurbitae* after being treated with *D. elliptica* mixed with Brewer's yeast at different time of exposure

The results also show significant (LSD, 0.1981, df = 5; $P<0.05$) difference in mortality of *B. cucurbitae* at different levels of concentration of *D. elliptica* in brewers yeast bait (Fig. 10).

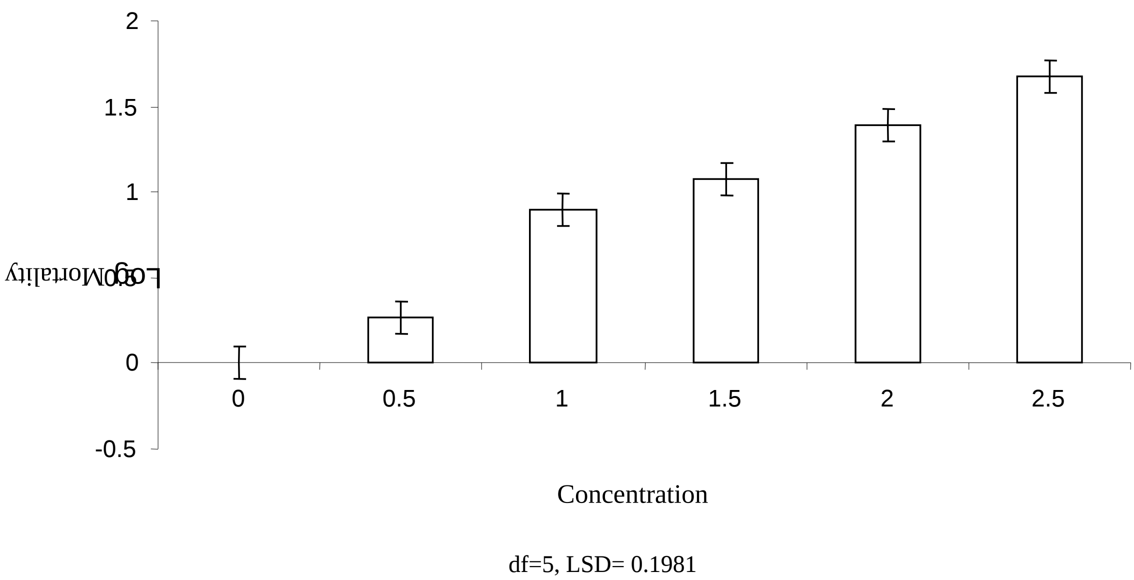


Figure 10: Mortality of *B. cucurbitae* after being treated with *D. elliptica* mixed with Brewer's yeast at different concentrations

Also observed was a significant difference (LSD, 0.3364, df = 10; $P<0.05$) in mortality of *B. cucurbitae* at different concentration and times of exposure to *D. elliptica* in brewer's yeast bait (Fig. 11). The results demonstrated that brewer's yeast and molasses could be good be used as food baits during laboratory bioassays.

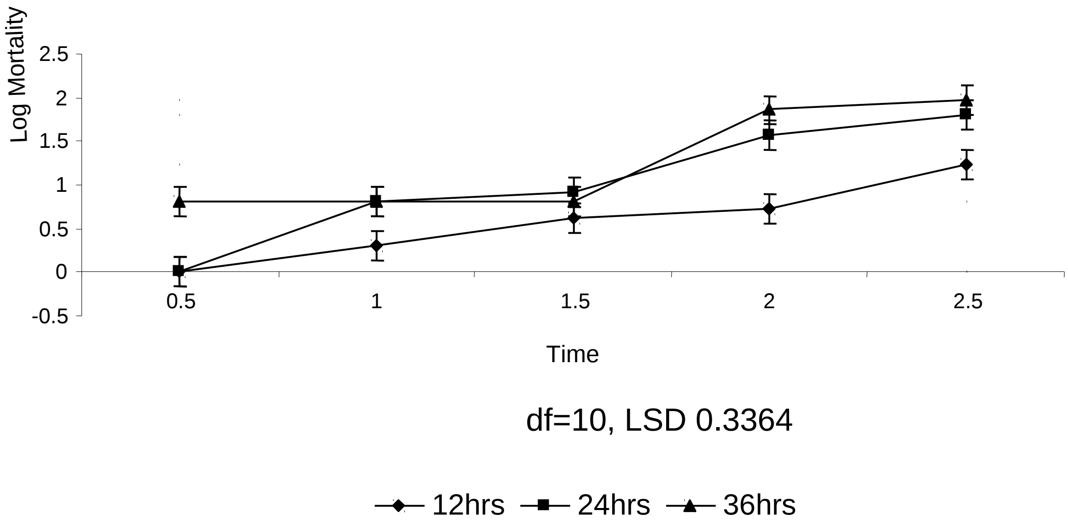


Figure 11: Mortality of *B. cucurbitae* after being treated with *D. elliptica* mixed with Brewer's yeast at different times and concentrations

The findings from this study showed that *D. elliptica* had effects on *B. cucurbitae*. Generally, these results indicate that the mortality of *B. cucurbitae* varied considerably depending on the type of baits and concentration applied. Mortality of 100% was reached after 36 hours of exposure of *B. cucurbitae* to treatment with 2.5 g/l of extracts.

4.3 The lethal dose of *D. elliptica* for *B. cucurbitae*

The toxicity of *D. elliptica* was evaluated in a laboratory bioassay whereby the concentration required to kill 50% of tested *B. cucurbitae* (LD_{50}) was calculated according to Finney (1971) probit transformation table. Probits mortality of *B. cucurbitae* was exposed to a series of concentrations of *D. elliptica* where by the LD_{50} was obtained at a corresponding probit value of 5 at 24 hours and 36 hours time of exposure on the tested number of *B. cucurbitae*.

Table 3: LD_{50} Log Concentr-ation of *D.elliptica* in Molasses mixed with Brewers yeast baits against *B. cucurbitae*

Log Concentration	Yeast	Molasses
LD_{50}	0.17383	-0.03298
Lower 90%	0.118	-0.0983
Upper 90%	0.1917	-0.0145
Natural scale		
LD_{50}	1.428	0.882
Lower 90%	1.312	0.797
Upper 90%	1.555	0.967

Table 3 shows the LD_{50} of both the molasses and brewers yeast based baits against *B. cucurbitae* when mixed with *D. elliptica*. The results demonstrate that brewer's yeast and molasses had effects at different concentrations with time of exposure at log concentration of 0.17383 and 0.03298 and the natural scale of 1.428 and 0.882, respectively. The reason could be due to the fact that, brewers yeast mixed with *D. elliptica* administered to *B. cucurbitae* in dry form while molasses when mixed with *D. elliptica* be in sticky moist, therefore *B. cucurbitae* likely favoured by dryness and or/ smell of brewers yeast than of molasses.

The results from this study show that, botanical extracts from *D. elliptica* had effects on *B. cucurbitae*. These results therefore indicate that *D. elliptica* is more effective when mixed with brewers yeast based baits. This is in accordance with the findings obtained by Akhtaruzzaman *et al.* (2000) that application of molasses and brewers yeasts based baits with other insecticides provide a good control of *B. cucurbitae* which makes the botanical extract more effectives in minimizing *B. cucurbitae* population. At lower concentration, living adults of *B. cucurbitae* continue to feed but slightly at slower rate. Death started occurring after 12 hours and percentage death increased as concentration and time increased.

4.4 Efficacy of Molasses and *D. elliptica* Baits in the Management of *B. cucurbitae* Under Field Condition

4.4.1 Efficacy of bait sprays in the management of *B. cucurbitae*

The efficacy of bait sprays in the management of *B. cucurbitae* in water melon was evaluated under field conditions. The treatment included *D. elliptica*, molasses, Dimethoate EC (40 g/l), Spinosad (GF-120) and untreated (control). Mean infestation results show to be significant (df = 3; LSD, 50.56. Botanical extracts (*Derris elliptica*) are also effective against *B. cucurbitae* compared with other treatments (Table 4).

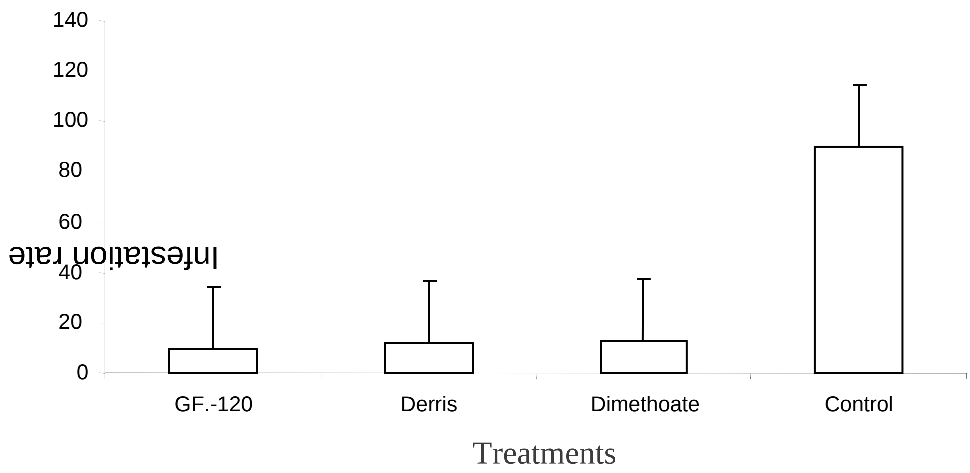
Table 4: Mean infestation rates of fruit fly species in water melon under different treatments

	Treatments					
Species	**Control**	**Derris**	**Dimethoate**	**GF.-120**	**SE**	**Mean**
B. cucurbitae	99.7	19.8	21.5	13.8	20.40	38.7
D. puctatifrons	28	6.3	11	8.6	4.94	13.5
D. bivitatus	52.8	1.2	4	0.2	12.78	14.6
D. ciliatus	11.1	2.1	2.2	0.5	2.41	4
D. vertebratus	257.1	29.4	24.6	22.7	57.90	83.4
Mean	89.7	11.8	12.7	9.2		30.8
Standard error	44.35	5.52	4.51	4.24	56.04	
LSD						50.46
df						3

Roessler, (1989) use mixtures of carbohydrates and other fermenting substances (such as molasses, sugars) in combination with inorganic insecticides in the managements of fly species including *B. cucurbitae* which were successfully.

Low infestation levels of *B. cucurbitae* in water melon were achieved by *D. elliptica* mixed with molasses, dimethoate EC 40 g/l and GF-120. High infestations of *D. vertebratus* were recorded and compared with other species. The similar result was observed by Akhtaruzzaman *et al.* (2000) after application of molasses plus malathion (Limithion 50 EC) and water success to control of *B. cucurbitae* populations

Apart from *B. cucurbitae* other fruit fly species observed after all the treatments were *D. bivitattus, D. ciliatus* and *D. vertebratus.* Furthermore, the results show that there were significant differences among the treatments i.e. botanical extracts (*D. elliptica)*, Dimethoate EC_{40}, Spinosad (GF-120) and Control (Fig. 12).



df=3, LSD = 50.46

Figure 12: Mean infestation rates of *B. cucurbitae* after treatments

However, the results show infestation rate of *B. cucurbitae* was also reduced in all the treatments when compared with other fruit flies species (Fig. 13). Therefore, this implies that botanical extracts i.e. *D. elliptica* have similar effects as synthetic pesticides for controlling *B. cucurbitae*. These results are in conformity with those obtained by Stoll (1987, 1988, and 1995), Schmutterer (1990, 1995) and Van Keullen (1994) that botanical extracts are effective against several insect species including melon fly, *B. cucurbitae*.Based on these results, botanical extracts from *D. elliptica* can provide adequate control of a wide range of fruit flies if properly applied.

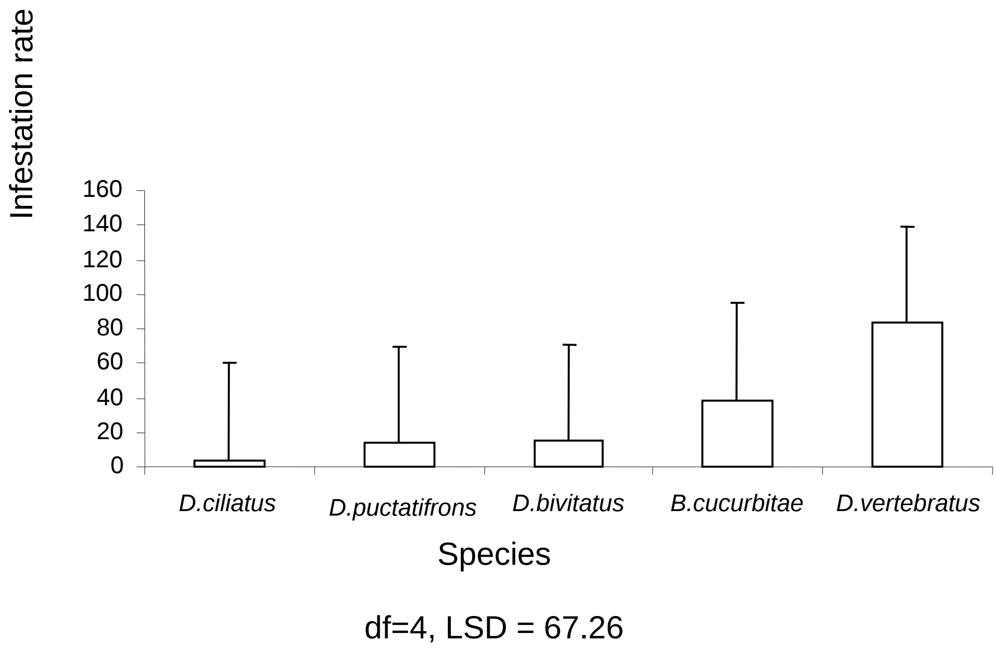


Figure 13: Mean infestation rates of fruit flies species after using four levels of treatments

On the other hand, botanical extracts (*D. elliptica*) mixed with molasses and sprayed on border crops show higher significant difference compared with the other treatments except control treatment. This is in accordance with the findings obtained by McQuate and Vargas

(2006) that in order to be effective bait sprays for the suppression of tephritid fruit fly populations require that they be applied in areas where the flies feed. The control treatment was found to have a very big number of fruit flies species as compared with other treatments. This implies that, the management of watermelon in controlling *B. cucurbitae* needs the application of synthetic or botanical pesticides. These will reduce *B. cucurbitae* population level, and this will subsequently lead to the increase of production of water melon.

4.5 Efficacy of Brewer's Waste and Molasses Baits in Monitoring *B. cucurbitae* Populations in the Water Melon Fields

4.5.1 Efficacy of monitoring baits

In these experiments of monitoring locally produced baits, the responses of lure in attracting flies species were observed to vary. During these studies the following species of fruit flies were trapped; *D. vertebratus, B. cucurbitae*, *B. latifrons and D. bivitattus*. A significant difference was observed in brewer's waste and molasses baits in monitoring flies populations by showing large number of means compared with solulys and protein bait (Table 5).

Table 5: Comparison of lures in attracting fruit fly species associated with cucurbits

Lure		Mean	n	Rank	Mean rank
Brewer's waste		1.25	8	159.5	19.94
Solulys		0.125	8	158.5	19.81
Molasses		1.25	8	121.5	15.19
Protein baits		0.625	8	88.5	11.06
Kruskal-Walli statistic		6.06			
X^2 statistic	=	6.06,		df =3,	P = 0.1085

Table 6: Pair wise comparison of lures in attracting fruit fly species populations

Attractants contrast	Difference	P.value
Molasses vs Protein baits	4.75	0.2433
Molasses vs Solulys	8.875	0.0342
Molasses vs Brewer’s waste	0.125	0.9752
Protein baits vs Solulys	4.125	0.3095
Protein baits vs Brewer’s waste	-4.625	0.2556
Solulys vs Brewer’s waste	-8.75	0.0366

The results also demonstrate that, pair wise mean comparison of lures in the case of molasses versus solulys and solulys versus brewer’s waste show a significant difference at F= 8.875 and 8.75, respectively by catching large numbers of *B. cucurbitae*. Furthermore, mean catches of *B .cucurbitae* by molasses versus protein baits, molasses versus brewer’s waste, protein bait versus solulys and protein bait versus Brewers waste were not significant (Table 6).

These results concur with the findings by (White and Elson-Harris 1992) that, *Bactrocera cucurbitae* was more attracted to the locally produced protein bait than it was to the imported protein due to the fact that, *B. cucurbitae* has a very wide host range, including non-cucurbits. The results demonstrate that, locally formulated protein baits show to be as effective in attracting *B. cucurbitae* flies as synthetic produced protein baits. The efficiencies of locally formulated baits in attracting fly species populations vary.

Table 7 to 14 show effectiveness of individual baits in attracting different fruit fly species among the four tested lures.

Table 7: Mean catch of fruit fly species by brewer’s waste

Species	n	Rank	Mean rank	Mean
B. cucurbitae	8	173.5	21.69	1.25

B. latifrons	8	116.5	14.56	0.375
D. bivitattus	8	118.5	14.81	1
D. vertebratus	8	119.5	14.94	1.5
Kruskal-Walli statistic				5.65
X^2 statistic = 5.65,		df =3,		P =0.1297

Table 8: Pair wise comparison of fruit fly species caught by brewer's waste

Contrast LSD	Difference	P. value
B. latifons vs B .cucurbitae	-7.125	0.0449
D. bivitattus vs B. cucurbitae	-6.875	0.0524
D. bivitattus vs B .cucurbitae	-6.75	0.0565

Mean catches of *B. cucurbitae* by brewer's waste were significant followed by *D. vertebratus* and their mean comparison of *B. latifrons* versus *B. cucurbitae* were also significant (Table 7 and 8).

Table 9: Mean catch of fruit fly species by molasses

Species	n	Rank	Mean rank	Mean
B. cucurbitae	8	167	20.88	1.25
B. latifrons	8	92	11.5	0
D. bivitattus	8	126.5	15.81	1.375
D. vertebratus	8	142.5	17.81	2.625
Kruskal-Walli statistic				6.25
X^2 statistic = 6.25,	df = 3,			P = 0.1

Table 10: Pair wise comparison of fruit fly species caught by molasses

Contrast LSD	Difference	P. value
B. latifons vs B. cucurbitae	-9.375	0.0151
D. bivitattus vs B. cucurbitea	-5.0625	0.1729
D. bivitatus vs B. cucurbitea	-3.0625	0.4047

Molasses also shows mean significance in catching large number of *D. bivitattus* followed by *D. vertebratus*, however their mean comparison of *B. latifrons* vs *B. cucurbitae* was also significance (Table 9 and 10).

Table 11: Mean catch of fruit fly species caught by protein baits

Species	n	Rank	Mean rank	Mean
B. cucurbitae	8	141.5	17.69	0.625
B. latifrons	8	119.5	14.94	2.75
D. bivitattus	8	100	12.5	0
D. vertebratus	8	167	20.88	3.875
Kruskal-Wallis'statistic				6.13
X^2 statistic = 6.13,	df = 3,			P = 0.1054

Table 12: Pair wise comparison of species caught by protein baits

Contrast LSD	Difference	P. value
B. latifons vs B. cucurbitae	-2.75	0.4201
D. bivitattus vs B. cucurbitea	-5.175	0.1339
D. bivitattus vs B. cucurbitea	3.1875	0.351

Mean catches of protein baits were highly significant in catching large number of *D. vertebratus* followed by *B. latifrons* although their mean comparison shows no significance difference versus fly species (Table 11 and 12).

Table 13: Mean catch of fruit fly species by solulys

Species	n	Rank	Mean rank	Mean
B. cucurbitae	8	104	13	0.125
B. latifrons	8	104	13	0.125
D. bivitattus	8	92	11.5	0
D. vertebratus	8	228	28.5	6.75
Kruskal-Wallis'statistic				26.07
X^2 statistic = 26.07,	df = 3,			P =0.0001

Table 14: Pair wise comparison of species caught by Solulys

Contrast LSD	Difference	P. value
B. latifons vs B. cucurbitae	0	1
D. bivitattus vs B. cucurbitae	-1.5	0.3616
D. bivitattus vs B. cucurbitae	15.5	<0.0001

Mean catch of fruit fly species by solulys show to be highly significant by catching large number of *D. vertebratus*. Morever their mean comparison of *B. latifrons* versus *B.*

cucurbitae was highly significant (Table 13 and 14). Overall results concur with finding by Gopaul and Prince (1999) that, commercial protein baits and locally made brewers yeast are widely used in fruit fly monitoring also locally produced brewers waste prepared from tusker brewery liquid were appeared to attracts large number of *B. cucurbitae* as the commercial protein hydrolysate.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 Performance of *D. elliptica* and molasses

D. elliptica and molasses have shown the potential of being effective in the management of *B. cucurbitae*. Botanical pesticides and locally produced baits were effective in the control of *B. cucurbitae*. Natural pesticides have the potential of being of use in agriculture especially with the dramatic increase in the consumption of organically produced plants. Clearly, the ability of Tanzania to produce its own substitute baits could make a major contribution to reducing the cost of production and enhancing the sustainability of *B. cucurbitae* control activities in the country.

5.1.2 Selection of roosting plant

In this study, maize plant was used as roosting plant and it has proven to be effective although no other plant was tested as a roost plant. However, more research is needed in finding and identifying other plant species which could be good roosting hosts. Examples of such crops are sorghum, castor bean, other wild plants, and weed plant species commonly found in the agricultural fields.

5.1.3 Monitoring *Bactrocera cucurbitae*

Four fruit fly species of economic importance were recorded in this study. All locally formulated and synthetic attractants show varying responses. Brewer's waste and molasses attract large numbers of *B. cucurbitae* versus *B. latifrons* hence it has proven to be effective. Furthermore, these botanical pesticides are affordable to low-income farmers.

5.2 Recommendations

The following recommendations are made regarding to this study;

5.2.1 Botanicals as an alternative to synthetic pesticides

Being able to use locally produced baits in large scale fruit fly control programmes will have a significant impact on the *B. cucurbitae* control activities in Morogoro. Since *B. cucurbitae* is the key pest of cucurbit species, it is recommended that the extracts of *D. elliptica*, molasses and brewer's waste and yeast be further tested for the consideration of its future use in Integrated Pest Management Programme on water melon production. Clearly, field testing of locally produced baits should be given a priority. For this reason, there is a need to encourage the production of protein baits from locally available waste materials.

5.2.2 Research on botanical plant species

Further research need to be done on botanical plant species like Neem (*Azadirachta indica*), Tephrosia (*Tephrosia vogelii*), Jatropher *(Jatropher curcas)*, and Pyrethrum (*Tanacetum cinerariaefolium)* for the management and control of *B. cucurbitae*. Further simple and cheap extraction techniques should be developed. Also isolation and identification of the active components of *D. elliptica* are also important. A study on the effect of spraying interval on performance of botanical extracts should be carried out.

5.2.3 Field sanitation

Field sanitation is a very important aspect during the whole period of production of water melon. After harvesting the crop, weeds and wild plant species must be removed from and near the fields to avoid populations build up of the flies species. Many times, weed and wild plant species could be good roosting hosts of the pests. However after harvest, crop residues and other farm wastes become a good environment of hatching and hibernation of crop pests. Therefore should be removed shortly after harvesting or to be buried 0.46 m under the soil.

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APENDICES

Appendix 1: ANOVA table for Bioassay of *D. elliptica* in molasses

SOV	d.f	s.s	m.s	F. value	Pf
Rep. stratum	4	0.027657	0.006914	4.51	
Rep. Time stratum.Time	2	4.145577	2.072788	1352.95	<.001
Residual	8	0.012256	0.001532	0.34	
Rp.T.Con.strtm.Conctrt	5	34.79773	6.959545	1550.79	<001
Time.Concentrn	10	1.061742	0.106174	23.66	<001
Residual	60	0.269264	0.004488		
Total	89	40.31422			

Appendix 2: ANOVA table for Bioassay of *D. elliptica* in brewer's yeast

SOV	d.f	s.s	m.s	F v.	pf.
Rep. stratum	4	40386	0.10096	1.49	
Rep. Time stratum.Time	5	31.05252	6.2105	91.81	<.001
Residual	20	1.35295	0.06765	0.93	
Rp.T.Con.strtm.Conctrt	2	10.4234	5.2117	71.63	<001
Time.Concentrn	10	3.69162	0.36916	5.07	<001
Residual	48	3.49229	0.07276		
Total	89	50.41663			

Appendix 3: ANOVA table of treatments for *B. cucurbitae*

Source of variation	d.f	s.s	m.s	f.v.	pf
Block stratum	2	23890	11945	0.87	
Block.*Units* stratum					
B. cucurbitae	3	256223	85408	6.21	<.001
Treatment	3	265382	88461	6.43	<.001
B. .cucurbitae .Treatment	9	378969	4210	3.06	<.002

			8 1375
Residual	126	1732491	0
Total	143	2656954	