THE EFFECT OF INSECTICIDAL PLANT MATERIALS ON THE QUALITY OF STORED BEANS

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL ENGINEERING OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

The research was conducted at the Department of Engineering Sciences and Technology of Sokoine University of Agriculture (SUA) to study the effect of insecticidal plant materials (neem and eucalyptus leave powder) on mortality of bruchid bettles and quality of stored beans for three months storage period. The objectives of the study were; To determine the effect of different concentrations of insecticidal plant materials on insect pests mortality in stored beans, to determine the effect of different concentrations of insecticidal plant materials on organoleptic qualities of stored beans and to determine the effect of different concentrations of insecticidal plant materials on seed viability of stored beans at different storage duration. Three rates (10, 20 and 30 g/kg) of each insecticidal plant leave powder, a synthetic insecticide (Shumba supermax dust at 0.5g/kg) and an untreated grain were used as treatments. The experiment was arranged in completely randomised design in four replications. Data collected include; Insect mortality, odour, taste and seed viability index of stored bean grains. Data collected were subjected to analysis of variance (ANOVA) using General Linear Model in SPSS computer software packages (version 16) and mean comparisons were conducted using Turkey's (HSD) test at 5% level of significance. Results showed a significant difference in percent mortality of adult bruchids due to the effect of insecticidal plant powders. The increase of adult bruchids mortality was directly proportional with the plant powder concentration. The application of insectical plant materials had influence on organoleptic quality of stored beans. However, the insecticidal plant powder had no significant effect on seed viability when compared to the controls. It can therefore concluded that, the insecticidal plant material can be used to protect grains against bruchid damage and on stored seeds for planting. For home consumption, the treated grain should be washed thoroughly with water to remove remained residue before use.

DECLARATION

I, Evance Kamanya Kabyazi do hereby declare to the senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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DEDICATION

This work is dedicated to the Almighty Father, Lord Jesus and my Parents: for the love and support. Secondly, special dedication to my lovely Wife, brothers and sisters for their advice, love and support.

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LIST OF SYMBOLS AND ABBREVIATION

ANOVA	Analysis of Variance
CRD	Completely Randomised Design
GLM	General Linear model
HSD	Honestly Significant Difference
Mc	Moisture content
Rh	Relative humidity
SPSS	Statistical package for the Social Sciences
w/w	weight/weight
Wb	wet basis
α	Alpha
%	Percentage
^{0}C	Degree Celsius

CHAPTER ONE

1.0 INTRODUCTION

1.1 Importance of Common Beans

Common beans (*Phaseolus vulgaris L.*) are the most important legume crops worldwide (Misangu *et al.,* 2007; Glowacka *et al*., 2015). They constitute a source of protein for the majority of households who cannot afford expensive animal protein on a daily basis; hence play a significant role in human nutrition, food security and income generation for small-scale farmers. Known as the "poor man's meat" in Eastern Africa, common beans are among several of the protein-rich plant sources commonly cultivated and consumed by low-income households across the region (Gomez, 2004; Maro, 2017). They are also a source of income for farmer households hence improve their livelihoods (Gomez, 2004). Furthermore, common beans have high concentration of various micronutrients including calcium, zinc, iron, and vitamin-B, which make them an important food for both human health and growth (Maro, 2017).

1.2 Common Beans Production

Globally, about 12 million metric tons of common beans are produced annually; with Latin America being the largest producer with 5.5 million metric tons. Africa ranks second in production with about 2.5 million metric tons. The leading beans producing countries in Africa include; Uganda, Kenya, Rwanda, Tanzania, Burundi, and Congo, with Tanzania's production estimated at 0.2 million Tons annually (Katungi *et al*., 2009).

1.3 Storage of Beans

Storage of beans is very important as it ensures food security and seed availability for the next season (Lal *et al*., 2017). Proper Beans storage plays an integral part in ensuring domestic food security and maintaining the quality of Beans throughout the storage period (Thamaga-Chitja *et al.*, 2004). In most areas beans are grown seasonally and after harvesting, beans are kept in safe storage conditions to maintain their quality throughout the offseason to ensure availability of food supply, seeds for next season, and selling surplus to earn money (Wani *et al*., 2014). The bean quality is influenced by several factors including; initial grain condition, storage conditions, moisture content, insect pests, bacterial and fungal infestation (Jaya *et al*., 2014; Wani *et al*., 2014; Lal *et al.*, 2017). Bean quality is based on numerous factors such as grain weight, grain damage, colours, aroma, moisture content, taste, seed viability and bulk density (Oshone *et al*., 2014 and Amruta *et al*., 2015). Therefore, to ensure bean quality and safety, all quality control measures should be observed during storage and handling practices (Ogendo *et al*., 2004; Amruta *et al*., 2015).

Insect pests are the main problem in stored bean grains because they affect both bean quality and quantity (Chahal, 2014; Edwin and Jacob, 2017). The susceptibility of the stored beans to insect pest infestation depends on several factors which include: initial grain condition, storage conditions, storage facilities, and insect pest control method used. The stored bean grains are attacked by different storage insect pests where bruchids are the most common insect pest (Mulungu *et al.*, 2007). Among the different species of bruchids, the common bean weevil (*Acanthoscelides obtectus* (Say) *and Zabrotes Subfasciatus* (Boh)) is known to pose serious post-harvest damage on common beans (Mulungu *et al.*, 2007). The presence of bruchids in stored beans results in reduced quality and quantity of beans. Globally, bean post-harvest losses are estimated at 20-30% annually (Umubyeyi and Rukazambuga, 2016).

Control of these pests is of prime importance in order to meet the demands of consumers, maintaining the quality of stored bean grains and sustain market standards (Chahal, 2014). Different technologies have been employed on controlling these pests, including environmental manipulation to hinder growth, feeding, maturation, and reproduction of storage pests (Boeke *et al*., 2001). These environmental manipulations have been attained by employing a number of control measures including chemical, cultural, mechanical and physical control. Among these control measures, chemical control using synthetic chemical insecticides has been observed to be the most effective and quick in controlling bruchids (Ogendo *et al.*, 2004 and Mulungu *et al*., 2007). However, its application by small-scale farmers is limited due to the high cost of these chemicals, infrequent supply, poor information, and lack of skills and knowledge on handling and proper application of these synthetic insecticides (Mulungu *et al*., 2007; Edwin and Jacob, 2017). They also, if not properly applied result in development of insect pest resistance, widespread environmental hazards and risk to non-target organisms (Ogendo, 2000). For these reasons, development of alternative means of insect pest control is inevitable. The use of insecticidal plant materials has gained significant importance in bruchid control due to the fact that it is friendly to both users and the environment (Rajashekar *et al*., 2012). The information obtained from this research will be useful if the efficacy of such botanical insecticidal materials is substantial.

Most farmers in the resource-poor farming environments protect their stored beans against bruchids using varieties of indigenous plants species with insecticidal properties for insect pest control (Ogendo, 2000). Insecticidal plant materials used in such controls include neem (*Azadirachta Indica*), eucalyptus (*Eucalyptus Glob*), ginger (*Zingiber offficinale*), wood ashes, pepper (*Capsicum frutescent*), and garlic (*Allium sativum* L). Several studies have been reported on the efficacy of insecticidal plant materials as grain protectants with many showing a high degree of effectiveness against the major storage pests such as bruchids (Ogendo, 2000; Reuben *et al.*, 2006; Mulungu *et al*., 2007; Muzemu *et al.*, 2013; Tamiru *et al.*, 2016). Despite the wide use of these insecticidal plant materials for insect pest control on stored bean grains, few studies have been reported on the optimal amount to be recommended for effective control and the side effects of these materials on the organoleptic quality of the treated grains. Therefore, this study aims at quantification of the efficacy of insecticidal plant materials in controlling of bruchids and their effect on the ogarnoleptic qualities of stored beans.

1.4 Justification

In Tanzania, beans form a significant part of the dietary diversity of many households. It is estimated that 80% of the rural communities, who depend on agriculture for livelihood and the urban poor, take common beans in their daily diet (Edwin and Jacob, 2017). The main challenge facing most of the smallholder farmers is proper beans storage and poor control of bruchids which cause both quantitative and qualitative losses and eventually affect them socially and economically. The post-harvest losses caused by the presence of bruchids have been estimated at 20-30% (Umbyeyi and Rukazambuga, 2015).

Majority of small scale farmers have been using synthetic chemicals to control stored insect pests in bean grains due to their effectiveness and quick action especially when the infestation is high. However, their application is limited not only due to high cost of these insecticides but also because they cause toxicity problems and handling difficulties. Because of these negative effects, the use of insecticidal plant materials have gained significant importance in controlling stored insect pests as an alternative to the synthetic chemical method. Insecticidal plant materials are readily available, cheap, easy to prepare, environmental and user friendly, safe to human beings and have more than one active ingredients (Edwin and Jacob, 2017). However, the use of such insecticidal plant materials to control bruchids in stored beans lack detailed information on the application rates and their side effects on the organoleptic qualities of treated beans.

Based on the above stated challenges, this study was conducted to provide valuable information on the optimal amount of insecticidal plant materials to be applied for effective control of bruchids in stored beans while maintaining the quality of stored beans. The study will contribute knowledge to smallholder farmers on how to control bruchids using insecticidal plant materials without affecting the quality of stored beans. The study will also, provide a basis for choosing between different insecticidal plant materials in controlling bruchids in stored beans. The selection of materials was based on their availability and frequency of use by small-scale farmers. Findings from this study will help various agricultural stakeholders such as policy makers, farmers, researchers and training institutions with regard to bruchids management in the endeavour to attain sustainable food security.

1.5 Objectives

1.5.1 Overall objective

The overall objective of this study was to evaluate the effect of using different insecticidal plant materials at different concentration on storage insect pests control and their effects on the organoleptic quality of stored beans.

1.5.2 Specific objectives

i. To determine the effect of different concentrations of insecticidal plant materials on stored bean pest control (bruchids) at different storage duration.

ii. To determine the effect of different concentrations of insecticidal plant materials on organoleptic qualities of stored beans at different storage duration.

iii. To determine the effect of different concentrations of insecticidal plant materials on seed viability of stored beans at different storage duration.

CHAPTER TWO

2.0 LITERATURE REVIEW

Grains produced by smallholder farmers are affected by insect pests, causing losses which affect the farmers socially and economically. Different chemical and non-chemical control methods have been employed to control insect pests in stored grains. Chemical control methods include the use of Organophosphates and fumigants and non-chemical control methods including the use of mechanical and physical methods, insecticidal plant materials, and minerals. The application of insect pests control methods differs in different regions or within farmers with different cultural background. Also, the effect and efficacy of these materials depend on application methods, amount applied and type of the material applied (Girma *et al.*, 2000; Kidane, 2005; Mpumi *et al*., 2016; Kesho, 2019).

2.1 Description of Some of the Insecticidal Plant Materials

Ginger (*Zingiber officinale* Rosc): Ginger extracts have been used as natural insecticides to control insect pests in stored grains. The extracts work effectively in controlling the stored insect pests in grains by causing mortality and producing repellent effect against insect pests (Ishii *et al*., 2010; Prakash *et al*., 2016). Also, El-Wakeil (2013) reported that ginger extracts perform effectively in controlling insect pests in stored grains due to their anti feedant and repellent effects against insect pests.

Neem leaves (*Azadirachta Indica*): Neem leave powder is a common and mostly used insecticidal plant material to control insect pests in stored grain mostly in Asia and Africa as an alternative to chemical insecticides. The extracts from neem seeds and leaves have been used as new insecticides that are considered to be environmentally friendly and having minimal mammalian toxicity. Neem products have a considerable potential in fighting insect pests on stored grains, where they react as feeding deterrent, toxic and inhibitor regulating growth rate of insect pest which depends on composition and preparation (Buss and Park-Brown, 2002; El-Wakeil, 2013).

Black pepper (*Piper nigrum*) and red pepper (*Capsicum frutescent*): These have been used to control insect pests in the stored grain such as maize and sorghum (Issa *et al*., 2011). Echezona (2006); Ashouri and Shayesteh (2009); Issa (2011) found that both black and red peppers have toxicity effect against insect pests in stored grains.

Ashes: Ashes have been used to control insect pests in stored grains. The combination of different ashes worked effectively in controlling insect pests in stored grain and they have no effect on the viability of grain seeds (Jean *et al*., 2015). Prakash *et al*. (2016) reported that ashes have feeding deterrent effect against stored insect pests. Also, ashes reduce the movement of insect pests for matting and reduce larval development of the storage insects. Ashes reduce the relative humidity of the storage condition and dry the surface of the stored grains (Prakash *et al*., 2016).

Eucalyptus leaves powder (*Eucalyptus globulus*): Eucalyptus leaves have been used to control insect pest in stored grains. Musundire *et al*. (2015); Mandudzi and Edziwa (2016) reported on the efficacy of eucalyptus in controlling insect pests in stored grains at different applications. Eucalyptus extracts have been proven to have repellent and insecticidal properties and have been used as grain protectants in developing countries (Muzemu *et al*., 2013).

2.2 The Mode of Application and Action of Insecticidal Plant Materials

Insecticidal plant materials extracts used in controlling insect pests can be applied in two ways, either by direct application on stored beans by using powders, aqueous extract and oil or fumigation using volatile compounds (Guzzo *et al*., 2006).

Plant-derived insecticides react against stored insect pests in different ways depending on the species of insect pests and the type of insecticidal plant material applied. Examples of plant-derived insecticides include leave powders, aqueous extracts, essential oils, and plant seeds powder (Tamiru *et al*., 2016). Insecticidal plant materials are not generally very selective as they may target a broad range of insect pests. Plant-derived insecticides may act in several ways as;

Repellents: some insecticidal plants have repellent effect against stored insect pests, as they drive insects away from stored grains mainly due to their unsuitable olfactory signals (Gahukar, 2008; Mpumi *et al*., 2016). Repellents from some plants are considered to be safe when used in insect pest control, as they are less harmful to the people, the stored products and to the environment. They also result in minimum residual effects compared to synthetic insecticides. The plant extracts, leaves and essential oils derived from insecticidal plants were reported to have repellent effects against stored insect pests (Rajashekar *et al*., 2012; Valsala and Gokuldas, 2015; Mpumi *et al*., 2016).

Feeding Deterrents: some plant extracts, leave powder and essential oils derived from insecticidal plants inhibit the insect feeding process by rendering treated materials unattractive (Mpumi *et al*., 2016). Extracts from neem plants and eucalyptus plants have been reported to act as feeding deterrents, which reduce food intake by insects as they make the treated grains unpalatable, hence starve them to death (Rajashekar *et al*., 2012).

Oviposition deterrents: some of the insecticidal plant materials act as oviposition deterrents where insect pests are prevented from laying eggs (Ahmad *et al*., 2018). Plant extracts, oils and leave powder when mixed with grain reduce oviposition and eggs hatchability on grains (Valsala and Gokuldas, 2015). Also, these plant products react as growth retardants and development inhibitors where they disrupt the normal life cycle of insects, thereby extending their lifecycle (Kuhne, 2008; Said and Pashte, 2015; Hikal *et al*., 2017).

Toxicants: some plants have toxic effects against different species of stored insect pests. They interrupt nervous system through feeding/skin contact hence cause death. Neem extracts, oil, powder, essential oil of garlic and oil derived from eucalyptus have shown to have toxicant effects against stored insect pest (Rajashekar *et al*., 2012; Hikal *et al*., 2017).

2.3 Advantage and Disadvantages of Insecticidal Plant Materials

Insecticidal plant materials provide a realistic alternative to synthetic chemical insecticides due to their safety to both the user and the environment (Buss and Park-Brown, 2002; Rajashekar *et al*., 2012). Insecticidal plant materials perform the specific action on the target pest and do not frequently result in insect resistance (Valsala and Gokuldas, 2015). The insecticidal plant materials work synergistically such that the combined efficacy of the two or more compounds is higher than that of a single compound (Tamiru *et al*., 2016). Insecticidal plant materials are biodegradable, reduce the risks of environment degradation and food contamination, and in most cases plant materials are readily available and easy to prepare. They also have fewer effects on man and non-target organisms and are easy to be adopted by smallholder farmers and have more than one active ingredient, which works synergistically, making them difficult for the insect pests to develop resistance (Guzzo *et al*., 2006 and Lal *et al*., 2017).

Despite the advantages of insecticidal plant materials, there are challenges that must be overcome if they have to be realized in both small scale and large scale grain protection. Insecticidal plant materials have a complex chemical composition and can have different biochemical targets on insects, but repeated and inappropriate use may result in insect pest resistance (Girma *et al.,* 2000). El-Wakeil (2013) also, reported that the use of insecticidal plant materials can offer protection of produce for a limited period and insect pest will overcome the efficacy of the protectants. These materials are relatively slow in their action compared to synthetic insecticides (Buss and Park-Brown, 2002). Also, there is variation in efficacy, poor persistence and inconsistence availability of insecticidal plants which may limit the potential of plant insecticides (Buss and Park-Brown, 2002). However, this information is contrary to the statement by Guzzo *et al*. (2006) that use of insecticidal plant materials cannot cause resistance to insect pests.

2.4 Common Bean (*Phaseolus vulgaris* L.)

The common bean (*P. vulgaris*) was introduced to Africa many years ago from the highlands of Central and South America where it was originated (Wortmann, 2006). The crop is grown in a wide range of geographic locations from high potential low-latitude sub-humid eastern African highlands to low potential mid-altitude in semiarid areas with acidic soils (Wortmann, 2006). Generally, the bean plants are polymorphic, having a variety of forms. They may be erect and bushy (up to 60 cm in height) or climbing (with stems up to 3 m long). They have compound leaves, with three smooth-edged oval leaflets that taper to a point. Flowering continues for two to three weeks, so pods develop at different times on the same plant. They range in shape from cylindrical to flat and usually contain from two to four seeds. The seeds come in a variety of shapes, sizes, and colours. They do poorly in very wet or humid tropical climates because of susceptibility to bacterial and fungal diseases. They need well-drained soils with PH between 6.5 and 7.0 and are sensitive to deficiencies or high levels of minerals in the soil (Broughton *et al*., 2003).

2.4.1 Uses of the common bean

The common bean is one of the principal food and a cash crop in Africa particularly in the eastern, southern and great lake regions of the continent (Katungi *et al*., 2009). Traditionally, the common bean is grown for home consumption, seed for the next season and for income generation. The crop is considered to be the most important source of human dietary protein in tropical and sub-tropical countries (Musundire *et al.*, 2015. In Tanzania, the common bean is one of the major pulse crops grown both as a source of the protein for local consumption, seed to be planted for the next season and export crop for earning foreign currency (Katungi *et al*., 2009). Many parts of the bean are for food, leaves, green pods, fresh and dry beans, of which fresh and dry beans are the most marketed products. Mature beans are usually threshed and dried, whereas green immature pods are marketed fresh, and eaten as a vegetable. Dried beans that do not meet human food quality standards are used as feedstock for livestock. Post-harvest plant remains are also used as feedstock for livestock.

2.4.2 Insect pests of beans

Insect pests are one of the major limiting factors for bean production in most developing countries. Numerous insect pests attack the common bean at different developmental stages of the crop that is from seedling to postharvest storage. Bean pests can be broadly classified into two: that is field and storage pests. However, only a few of them are considered as major pests of which are bean stem maggots (*Ophiomyia* spp.) and bean bruchids as the most economically important field and storage pests, respectively.

2.4.3 Insect pests of stored beans

Many insect species attack stored beans but most of these species migrate from other products like maize, sorghum or rice stored in the same warehouse and cause minor damage to beans. The common species causing severe damage to stored beans is bean bruchids (*Acanthoscelides obtectus* (Say) *and Zabrotes subfisciatus* (Boh)), which belong to the family Bruchidae. Common bean weevils have been reported to be widely distributed and cause heavy qualitative and quantitative losses (Ebinu *et al*., 2016; Tamiru *et al*., 2016). The attack by bruchids starts in the field or stored beans where the female bruchid lays eggs on the ripening pods of the crop or on stored beans. The larvae bore into the bean seeds, feed and proceed to develop inside the seed. The larvae of bruchid stay undetected in the seed until the adult emerges. The presence of mature adults is recognized by the small circular window on the bean seeds. The newly formed adults remain in the cell for several days before exiting the seed. The newly emerged adults mate immediately and oviposition starts (Tamiru *et al*., 2016). The life cycles of *Acathoscelides obtectus* and *Zabrotes. subfusciutus* are completed in about 28 and 24 days, respectively. Respective adult longevity for the two species is approximately 14days (Tamiru *et al*., 2016).

2.4.4 The effect of bean bruchid damage

Bean bruchids are among the insect pests that decrease bean production due to high postharvest losses they cause during storage. Bean bruchids attack results in both quantitative and qualitative losses due to their feeding. The degree of loss due to bruchid depends on the storage period, storage conditions, storage structures and varieties of bean grains. Bruchid damage results in a decrease of the nutritional value of the stored products and change in the cooking characteristic of the stored beans (Mulungu *et al*., 2007). Ebinu *et al*. (2016) reported that the bruchid damage causes a reduction in grain weight and seed viability because bruchids usually attach seed embryo. Bruchid attack also causes decrease of acceptability of attacked beans in the market due to change in appearance and in flavour. Apart from that, bruchid damage increases deterioration, contamination, mold attack, change in aroma and heat damage problems that reduce the quality of stored beans and make it unfit for human consumption and planting in the next season (Azeez and Pitan, 2018). Due to these losses, farmers grow relatively small amount of beans and sell them immediately after harvest at a relatively low price to avoid huge losses which affect them socially and economically (Ebinu *et al*., 2016).

2.4.5 Control

Insect pest control is among the very important practices that must be carried out to ensure the quantity and quality of stored grains are maintained. There are different insect pest control methods that can be deployed to control pest before their damage become economically important. They are deployed based on the nature of pests, the population of pests and the cost of control methods (Kesho, 2019). Farmers use both cultural and chemical management strategies to prevent quantitative and qualitative losses due to bruchid attack. These control methods involve the manipulation of the storage environment to make it unfavourable to bruchid infestation. They include storage hygiene, harvesting on time before splits appear, removal of infested grains, drying seeds thoroughly to the recommended storage moisture content, rolling of seeds in a drum to crush eggs and stop new larvae from penetrating the seeds, use of resistant varieties, admixing grains with ash and botanicals and use of chemical insecticides. To ensure food security and quality of beans, all control measure should be observed (Ogendo *et al.*, 2004; Kesho, 2019).

2.4.5.1 Cultural control

Store hygiene is the foremost preventive factor in pest control in stored grain. Storage structures and their immediate surroundings must be kept as clean as possible. Removal of old grains and residue of organic matter present in storage structures, and old bags is important in the preparation of the insect-free environment and prevention of carryover of pests to new grain. A newly harvested grain should never be stored with remainders of the previous harvest as well as in used bags without washing/disinfecting (Kidane, 2005). However, it should be pointed out that practical hygienic control can bring satisfactory results if it is combined with good and adequate drying.

Farmers used a range of traditional methods of control or devised strategies to cope with insect infestation, which were passed from one generation to the next. The most common traditional treatments to limit insect activities are mixing grain with inert materials and organic materials. The friction of inert dust particles with the insect's cuticle leads to desiccation and hampers the development of the pest (Kidane, 2005). A similar effect can also be achieved through treatment with wood ash collected from burnt tree wood or a farmer’s kitchen. Some farmers may also add fine sand to hinder the insect pest activities, in which the high proportion of quartz damages the sensitive cuticle of the newly hatched insect (Girma *et al*., 2000; Kidane, 2005). Exposure to sunlight followed by sieving of the grains usually at a monthly interval is also a well-known technique among small scale farmers as it creates an unfavourable environment for weevil infestation (Girma *et al.*, 2000 and Kidane, 2005). Other traditional methods include winnowing, shaking, restacking grains bags and mixing grains with small sized grains to reduce insect activity.

2.4.5.2 Control using insecticidal plant materials

The use of plant materials as traditional protectants of stored products is an old practice used all over the world. Mixing the grain with insecticidal plant materials or extracts derived from local plant materials such as neem tree, pepper, garlic and eucalyptus which have toxic, antifeedant, repellent or growth regulator properties has met with varying degree of success in controlling bruchids in stored grains (Tamiru *et al*., 2016; Kesho, 2019). These botanicals have insecticidal properties, working in the same mode as commercial insecticides. However, botanicals have several modes of action. Toxicity against insect may be expressed by direct killing particular life stages of the insect, interfering with mating patterns, suppressing reproduction, acting as a repellent and selection in a way that prevents infestation, reducing or preventing feeding (Rajashekar *et al*., 2012; Mpumi *et al*., 2016; Ahmad *et al*., 2018). Plant products can be obtained either from the whole plant or from a specific part of the plant. The most common way of using plants in post-harvest protection is the admixture of plant powders, oils and more purified insecticides including the use of essential oils and organic solvent extracts (Guzzo *et al*., 2006). Use of plant products is one of the important approaches of insect pest management and has many advantages over synthetic insecticides (Zewde and Jembere, 2010). Plant materials with insecticidal properties provide alternative to synthetic chemicals because they are readily available, biodegradable, and easy to prepare and have low toxicity to human and the environment.

2.4.5.3 Chemical control

This control measure has been frequently employed in both small and large scale grain legumes storage to control bruchid damage below the severe economic injury level. The effect and efficacy of these chemicals are achieved, if they are used at the right time, in the right quantity, with the right application methods and in a conducive environments.

However, financial and technical constraints among farmers reduce the use of chemical insecticides (Kesho, 2019). Dusting and fumigation of grains are the most commonly used chemical methods. Dusting is an easily applied method, and can be implemented using very cheap tools such as cloth bags or small containers with punctured holes in the lid. For small amounts of grain, dust can be mixed with grain using a shovel. Dust should be mixed thoroughly and distributed evenly all over the produce. Dust can also be applied on floors, flat surfaces and around the bottom of storage containers. The most commonly used insecticides dust among farmers for control of bruchids is Malathion, deltamethrin, permethrin, and primiphos-methyl (Kidane, 2005; Kesho, 2019).

Fumigants are low molecular weight chemicals, highly toxic and volatile and are, therefore self-dispersing and non-persistent. Fumigation is a widely used method all over the world, particularly for large-scale grain storage. Fumigants have the ability to kill all insect stages residing in the grains but do not protect grain from new attacks. Fumigants must be used in airtight condition. The most widely used fumigants are Phosphine (PH_3), Carbon tetrachloride and hydrogen cyanide (Manson and Obermeyer, 2004; Kidane, 2005). The usefulness of the chemical control has been limited due to prohibitive very high cost of the chemicals and inadequate training of farmers on how to apply and handle these chemicals which in most cases lead to improper application, resulting in insect pest resistance and human health hazards (Ogendo, 2000; Mulungu *et al*., 2007; Kesho, 2019).

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 Description of the Study Area

The study was conducted in Bioprocess and post-harvest Engineering laboratory at the Department of Engineering Sciences and Technology of Sokoine University of Agriculture in Morogoro, situated at 6.85°S latitude, 37.65°E longitudes, and altitude 533m above the sea level.

3.2 Experimental Materials

Common beans (*Phaseolous vulgaris L*) were used during the study. A sample of freshly harvested common beans were purchased from local market and sun-dried to a recommended storage moisture content of 12% wb (Lopes and Neto, 2019). The dried beans were then cleaned and all foreign materials were removed. Clean beans were packed in 5 kg polythene bags and kept in the laboratory under room conditions with temperature of 28.95 ± 0.15°c and relative humidity of 49.43 ±1.09% before the experiment.

Insecticidal plant materials (eucalyptus and neem leaves) were collected from the fields near the University. The collected leaves of neem and eucalyptus were air dried under shade at room temperature of 28.95 ± 0.15°c and relative humidity of 49.43 ± 1.09% to moisture content of about 9% (wb) for two weeks. After that, the dried leaves were then milled using wooden mortar and pestle, and sieved using a 0.5 mm mesh to get a fine powder. The fine powder was packed in plastic bags and kept in the laboratory before the experiment. Shumba SuperMax dust (Primiphos Methyl 1% and Deltamethrin 0.13%)

commonly used by small scale farmers as synthetic chemical insecticides was purchased from Agrovet shop.

3.3 Grain Treatment

Ground powders of neem and eucalyptus leaves at three rates (10, 20 and 30 g/kg) (Tamiru *et al.,* 2016) were admixed with 5 kg of common beans. An untreated sample was used as a negative control while a synthetic insecticide (Shumba supermax) dust at the recommended rate of 0.5g/kg was used as positive control. Adult bruchids used for the experiment were obtained from infested beans bought from the local market where 40 bruchids were introduced to each replicate as initial infestation. A total of eight treatments (Table 3.1), each replicated four times, were arranged in a Completely Randomised Design (CRD) on one metre high tables in the laboratory. All treatments were kept at ambient temperature of 29.11± 0.07^{o}c and relative humidity of 56.87± 0.36%. Below (Table 3.1) is the list of test leave powder used during experiment for beans quality evaluation.

Table 3.1: **Treatments used for the grain quality evaluation**

Treatments	**Description**	**Dosages (g/kg)**
T_0	Untreated	0.00
T_1	Shumba SuperMax dust	0.5
T_2	Neem leave powder	10
T_3	Neem leave powder	20
T_4	Neem leave powder	30
T_5	Eucalyptus leave powder	10
T_6	Eucalyptus leave powder	20
T_7	Eucalyptus leave powder	30

Table 3.2: Quality parameters of the grains at the start (day 0) of the bean grain quality evaluations

Quality parameters	Value
Seed viability index (%)	96.25±1.44
Moisture content (%)	12± 00
Mortality (%)	00± 00
Odour	odourless
Taste	Tasteless

3.4 Grain Sampling and Sample Analysis

Approximately 500g sample was collected from each replicate using a cylindrical grain sampler (25 mm in diameter). A rotary cone sample divider was used to subdivide sample into approximately eight equal portions out of which four portions were randomly selected to get a working sample of 250g for beans quality analysis. The sub-sample was used to determine the grain quality parameters which included seed viability index (%), grain odour (aroma) and taste.

3.5 The Effect of Insecticidal Plant Material Concentrations on Storage Bean Pest Control

Different varieties of insecticidal plant materials or their extracts have been used to protect grains against storage insect pests and have shown to cause a number of insect population depressing effects such as mortality (Hikal *et al*., 2017), anti-oviposition (Hikal *et al*., 2017) repellence (Mpumi *et al*., 2016) and feeding deterrents (Rajashekar *et al*., 2012) when applied against storage insect pest. For this study, the efficacy of insecticidal plant powder to protect stored beans against bruchids was assessed in terms of mortality of adult bruchids. A sample was taken from each replicate, sieved and the number of dead insects were counted and recorded and percent mortality of adult bruchids was evaluated by counting number of dead insects in each treatment every day for 5 days after treatment. On the fifth day all insects (live and dead) were separated and removed from treatments and the cumulative data on percent mortality of adult bruchids was calculated. After, the mortality assessment the beans were further stored for bean quality evaluation. The mortality of adult bruchids was calculated by using Abbott’s formula as described by Tegegne (2017).

$$Pt = \frac{Po - Pc}{100 - Pc} \times 100 \ldots\ldots \quad (1)$$

Where; Pt = percent (%) mortality; Po = observed mortality; Pc = control mortality

3.6 Effect of Insecticidal Plant material Concentrations on Organoleptic Qualities on Stored Beans

The effect of insecticidal plant material on organoleptic quality was evaluated by using a trained test panel. Selection of the panelists was based on their availability during the study, interest to the project and experties in sensory evaluation. The changes in organoleptic qualities (odour (aroma) and taste) of both treated and untreated common beans was evaluated by the group trained panelists twice per month for three months period of study. Sensory evaluation of beans was conducted by 10 trained panelists from Department of Food Sciences and Technology and Department of Engineering Sciences and Technology with age ranging from 20 to 30 years. Panelists were exposed to 2-h training sessions on 4 consecutive days in order to develop a clear definition for each attribute in common beans organoleptic qualities. Each panelist received a sample of common beans and trained to increase their ability to discriminate sensory attributes of the given sample. In order to ensure that panelists were not influenced in any way, no information with regard to the nature of the samples was provided and Panelists were reminded not to use perfumed cosmetics and to avoid exposure to food stuffs at least 30 min before evaluation sessions.

The change in grain colour and odour (aroma) of both treated and untreated bean grains was assessed using scoring scale of one to five (1-5) points as described by Musundire *et al.* (2015). The sample drawn from each treatment was cleaned to remove residue particles before given to panellists for organoleptic quality evaluation. Samples were assessed on change in odour (Table 3.3) and taste (Table 3.4) by using scoring scale of one to five (1-5) points that was defined separately for each of the two parameters.

Table 3.3: Scoring for change in grain odour (aroma) scale 1 to 5

Score	Description
1	Grain is odourless
2	Grain has little offensive odour
3	Grain has moderate odour
4	Grain has offensive odour
5	Grain has very offensive odour making grain unacceptable for human consumption

Table 3.4: Scoring for change in grain taste scale 1 to 5

Score	Description
1	Grain is tasteless
2	Grain has little bitter taste
3	Grain has moderate bitter taste
4	Grain has bitter taste
5	Grain has very bitter taste making grain unacceptable for human consumption

To obtain unbiased scores, each sample was coded with 3-digit random numbers. The coded samples were presented in a well-lit and ventilated room for assessment. Panelists were allowed into the assessment room and sample was given in a randomized order and instructed to rate the sample in terms of odour (aroma) and taste attributes. Each panelist was given questionnaire sheets for each sample during data collection. New questionnaire sheets were used for each assessment date to ensure there was no bias from the previous data.

3.7 Effect of Insecticidal Plant Material Concentrations on Seed Viability

The effect of treatments on seed viability expressed as germination percentage was evaluated during storage period. Data on seed viability were collected at 14 days interval for three months storage period after setting the experiment. One hundred undamaged bean grains were selected randomly from each sample of treatments. The grains were then germinated on moist sand substrate in a germination box. The germination box was placed in the germination chamber maintained at a temperature and relative humidity of 25ºC and 65%, respectively. The seed germination was evaluated on ninth day after planting (ISTA, 2018). Normal and abnormal seedling and dead seeds were counted and recorded. The normal seedlings were used to calculate the percentage germination of the stored beans. Percentage germination was computed according to Ogendo *et al*. (2004) formula.

$$\% Viability\, index = \frac{NG}{TG} X\, 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where;

N_G is the number of seed that germinated

T_G is the total number of seed tested for germination

3.8 Data Analysis

All the experiments were laid in a completely randomized design (CRD). Data entry and analysis were done using Microsoft Excel and SPSS software (version 16). All data were checked for normality before they were subjected to analysis. Data were analysed with analysis of variance (ANOVA) using General Linear Model (GML) to find out the effect of different treatment concentration on pest control (mortality), odour, taste and seed viability index at different storage duration and mean comparisons were conducted using Turkey's (HSD) test at 5% level of significance.

CHAPTER FOUR

4.0 RESULTS

The influence of insecticidal plant powder treatments on the quality of stored beans grain was investigated, and the mortality, germination percentage and change in odour and taste over three months of storage period are presented in figure 4.1 to 4.3 below. The results showed that there was a significant difference ($P < 0.05$) between treatments in all quality parameters tested during three months of storage.

4.1 Effect of Insecticidal Plant Material Concentrations on Stored Beans Pest Control (Mortality) at Different Storage Duration

The results of this study showed a significant difference ($F_{7, 24}$=1006, p= 0.0001) in the mean percent mortality of adult bruchids due to insecticidal plant powder applied on stored beans at different dosage (Figure 4.1). The percentage mortality of adult bruchids in stored beans treated with either neem or eucalyptus leave powder were significantly different at all (10, 20, 30 g/kg) concentrations. The neem leave powder treatment caused 57.5, 67.5 and 86.25% mortality of adult bruchids while eucalyptus leave powder treatment caused 50.00, 63.75 and 71.25% mortality of adult bruchids at 10, 20 and 30 g/kg concentrations respectively (Figure 4.1).

The bruchid mortality increases with an increase of both eucalyptus and neem powder dosages. Compared to the positive control and negative control, the highest bruchid mortality was recorded in 30 g/kg concentration while the lowest was recorded in 10 g/kg concentration of both two insecticidal plant material used. There was no adult mortality observed in control treatment.

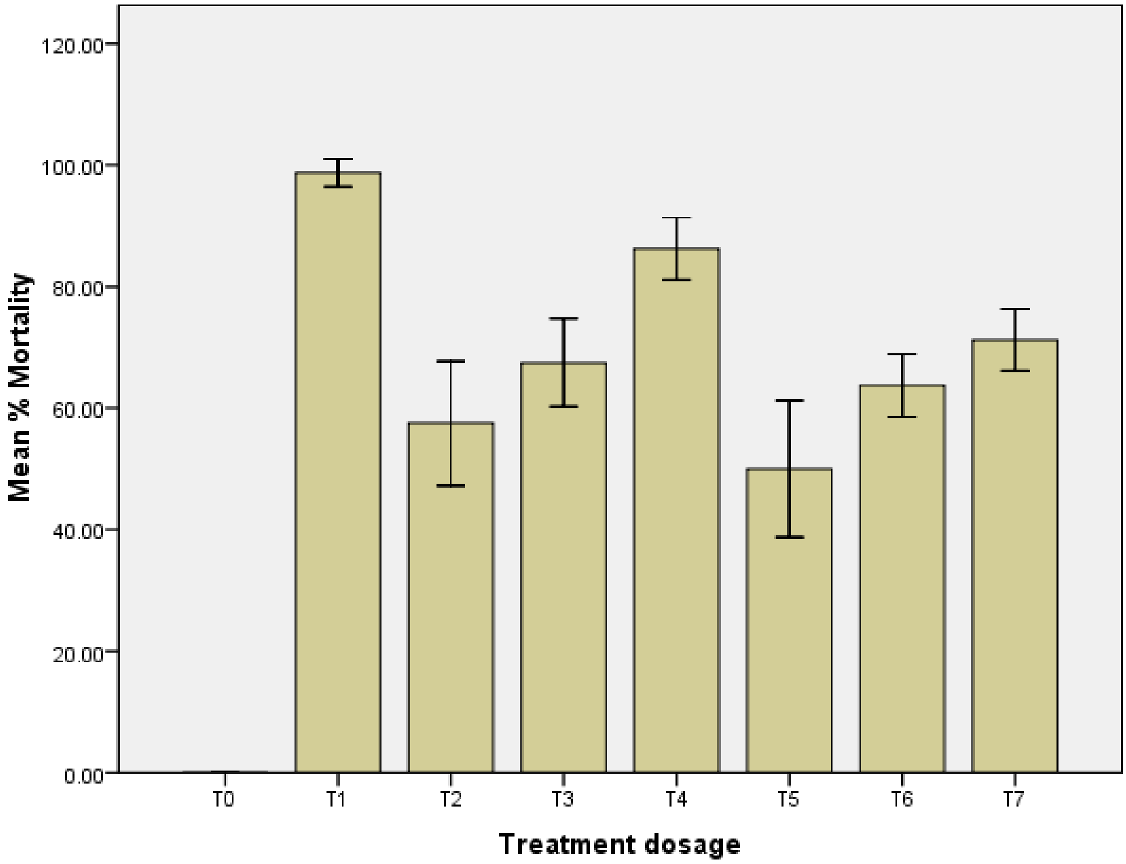

Figure 4.1: The effect of treatment concentrations on mortality of adult bruchid in stored beans.

Where; T_0 is untreated grains, T_1 is Shumba supermax dust as synthetic chemicals at 0.5 g/kg , T_2 is neem leave powder at 10 g/kg, T_3 is neem leave powder at 20 g/kg , T_4 is neem leave powder at 30 g/kg, T_5 is eucalyptus leave powder at 10 g/kg, T_6 is eucalyptus leave powder at 20 g/kg and T_7 is eucalyptus leave powder at 30 g/kg.

4.2 Effect of Insecticidal Plant Materials Concentration on Organoleptic Qualities of Stored Beans at Different Storage Duration

The changes in quality attributes of stored beans in terms of odour and taste after treatment application are as shown in Figure 4.2(a and b). There was significant different ($p<0.05$) for treatment on the quality attributes of stored beans.

The treatment effects on odour of the stored beans were statistically significant ($F_{7, 2232}$=2320, p= 0.0001). The mean odour score for stored bean grains increased with dosage of the applied insecticidal plant materials (Figure 4.2a). The highest odour score (1.55) was recorded in the grains treated with Shumba super max followed by grains treated by neem and eucalyptus leave powder at 30 g/kg same application rate (Figure 4.2a) and the lowest odour score (1.28) was recorded in untreated control of the stored bean grains. However, the changes in beans odour in all treatment rates were mainly between odourless and less offensive odour where all treatments rates scored less than two on the five point scale used.

Similarly, the results indicated that there was significant difference ($F_{7, 2232}$=1833, p= 0.0001) on taste of stored beans due to the effect of insecticidal plant materials (Figure 4.2b). The highest taste score (2.01) was recorded in the grains treated with neem leave powder at 30 g/kg, followed by those treated by eucalyptus leave powder at 30 g/kg with taste score of 1.96 while the lowest taste score (1.18) was recorded in untreated control of the stored bean grains (Figure 4.2b). There was no statistical difference on taste score of bean grains treated with 10 and 20 g/kg and those treated with synthetic chemicals.

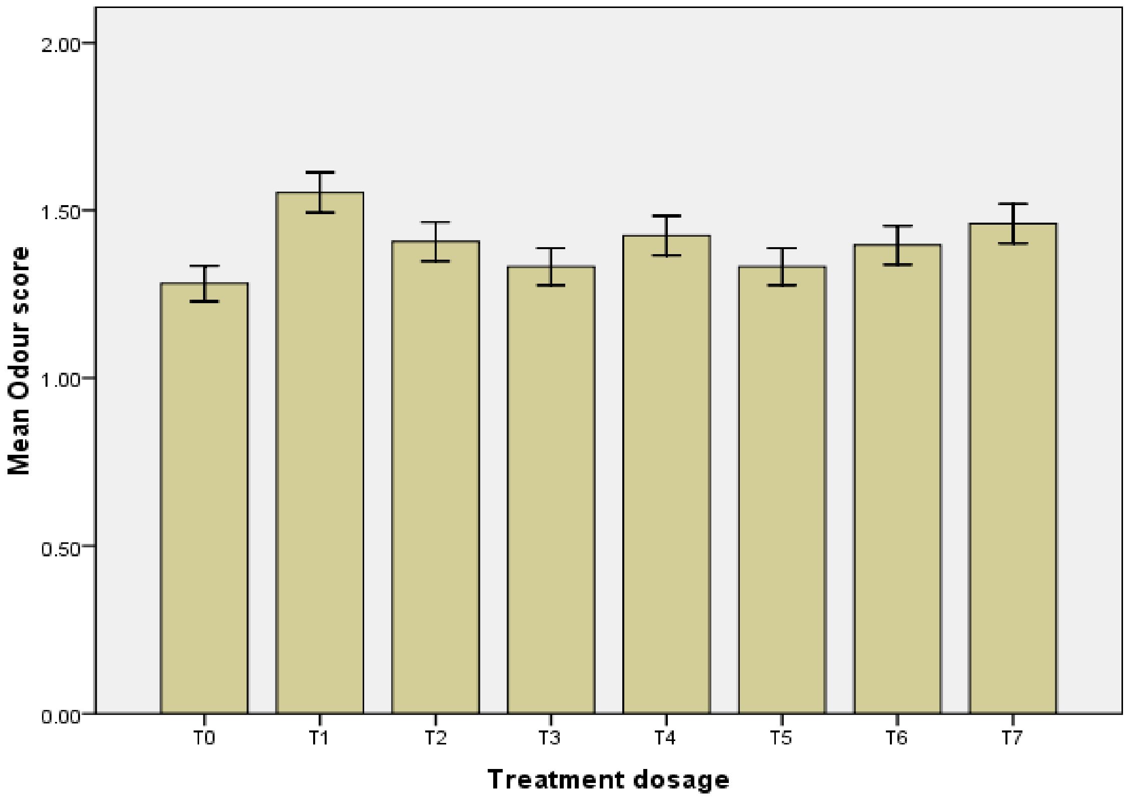

Figure 4.2 (a): **The effect of treatment concentrations on odour attributes of stored beans.**

Where; T_0 is untreated grains, T_1 is Shumba supermax dust as synthetic chemicals at 0.5 g/kg , T_2 is neem leave powder at 10 g/kg, T_3 is neem leave powder at 20 g/kg , T_4 is neem leave powder at 30 g/kg, T_5 is eucalyptus leave powder at 10 g/kg, T_6 is eucalyptus leave powder at 20 g/kg and T_7 is eucalyptus leave powder at 30 g/kg

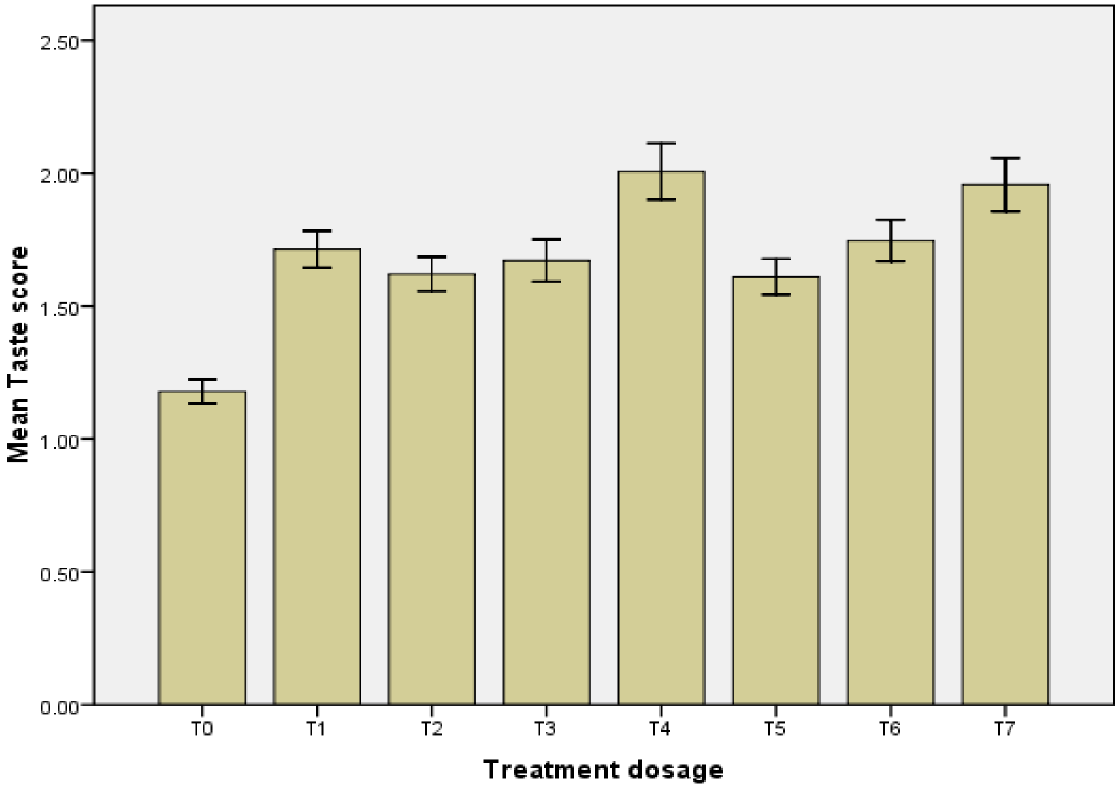

Figure 4.2(b): **The effect of treatment concentrations on taste attributes of stored beans.**

Where; T_0 is untreated grains, T_1 is Shumba supermax dust as synthetic chemicals at 0.5 g/kg , T_2 is neem leave powder at 10 g/kg, T_3 is neem leave powder at 20 g/kg , T_4 is neem leave powder at 30 g/kg, T_5 is eucalyptus leave powder at 10 g/kg, T_6 is eucalyptus leave powder at 20 g/kg and T_7 is eucalyptus leave powder at 30 g/kg

4.3 Effect of Insecticidal Plant Materials Concentration on Seed Viability index of Stored Beans at Different Storage Duration

The results of the effect of insecticidal plant materials concentrations on seed viability of stored beans during the storage period are presented in Figure 4.3. Results from the study indicated that seed viability of treated and control grains were all significant at ($F_{7, 216}$=8592, p=0.0001) during storage period (Figure 4.3). However, the treated beans had higher germination rate compared to untreated beans. Both treated and untreated beans seed viability ranged between 92.08-82.89% germination during the storage period. The highest seed viability was observed on stored bean grains treated with synthetic chemical (shumba max) (93.89%), followed by those treated with insecticidal plant powder. Grains treated with T_3 (20 g/kg) neem leave powder had the seed viability of 90.61%, followed by T_4 (30 g/kg) that had seed viability of 90.00% and T_2 (10 g/kg) that had seed viability of 86.82%. Seed treated with eucalyptus leave powder T_5 (10 g/kg) had seed viability of 89.39%, followed by T_7 (30 g/kg) that had seed viability of 89.07 and T_6 (20 g/kg) with seed viability of 86.82%. Untreated bean grains had the lowest seed viability of 82.89%.

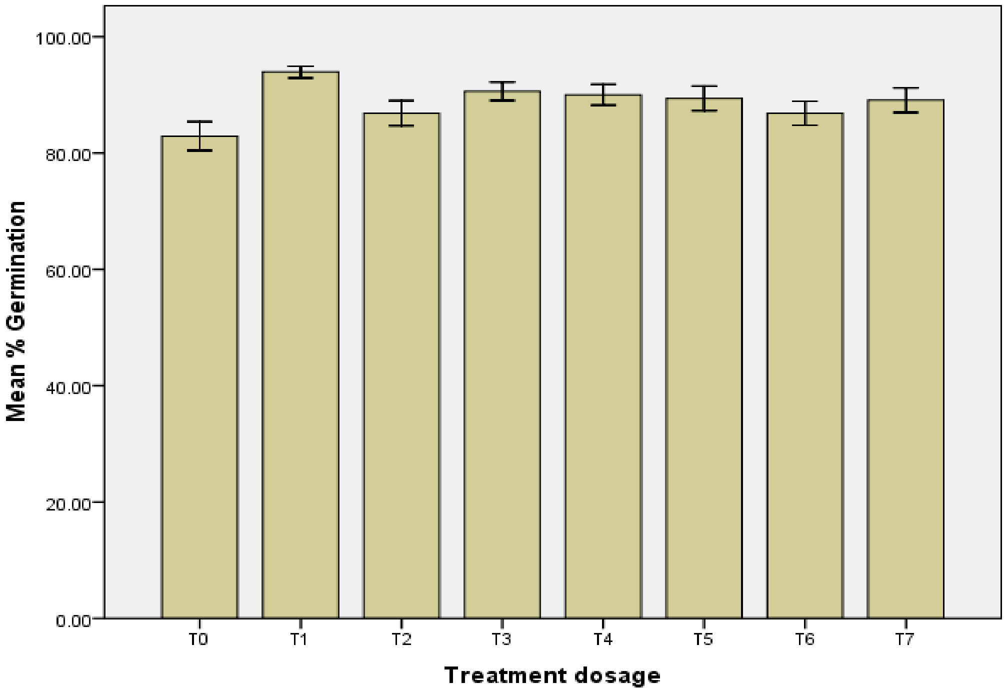

Figure 4.3: Effect of treatment concentrations on seed viability index of stored bean grains.

Where; T_0 is untreated grains, T_1 is Shumba supermax dust as synthetic chemicals at 0.5 g/kg , T_2 is neem leave powder at 10 g/kg, T_3 is neem leave powder at 20 g/kg , T_4 is neem leave powder at 30 g/kg, T_5 is eucalyptus leave powder at 10 g/kg, T_6 is eucalyptus leave powder at 20 g/kg and T_7 is eucalyptus leave powder at 30 g/kg

CHAPTER FIVE

5.0 DISCUSSION

5.1 The Effect of Treatment Concentration on Mortality of Storage Insect Pest

This study demonstrated the potential of eucalyptus and neem powder as natural protectants of stored beans against bruchid damages. This protection is due to presence of insecticidal properties within these plants with active compound that reacts against the storage insect pests**.** Neem leave powder for instance has been reported to contain an active compounds such as azadirachitin, meliantriol, salannin, Nimbin and Nimbidin which can protect the storage beans from insect damage (Rajashekar *et al*., 2012; Hikal *et al*., 2017).

Similarly, eucalyptus has been reported to contain various active compounds such as eucalyptin, rutin, gentisic acid and 1, 8 cineole which are active against storage insect pests (Muzemu *et al*., 2013; Tegegne, 2017). When insects feed on grains treated with these plant extracts containing these bioactive compounds can suffer through various ways including growth inhibition, repellents, feeding deterrents and lethal effects (Tegegne, 2017; Hikal *et al*., 2017). The results from this study is similar to many studies (Rajashekar *et al*., 2012; Muzemu *et al*., 2013; Mpumi *et al*., 2016 and Hikal *et al*., 2017) which have reported insecticidal plant extracts be an effective control against major insect pests of stored grains.

The findings of this study also indicated the existence of the relationship between the amount of leave powder applied and their effect against insect pests. The present study showed that the mortality of adult bruchids exposed to neem or eucalyptus leaf powder increased with an increased in concentration levels of the botanical leave powder.

This implies that higher mortality could be achieved through the increase in the dosage of leaf powder. These results are in line with the study conducted by Rosemary *et al*. (2018) which reported that increase of the concentration of neem leaf powder results in increased mortality of adult American cockroach (*Periplanata americana*). In addition similar results conducted by Erenso and Berhe (2016) reported on the efficacy of neem leave powder against maize weevils whereby increase in concentration (from 1 to 3%w/w) led to increased mortality of adult weevils from 61.13% to 77.75%.

Furthermore, findings of this study are supported by the results from the study conducted by Mandudzi *et al.* (2015) who reported on the effectiveness of eucalyptus leave powder against *Sitophilus zeamias* L in stored maize grains. Mortality of adult weevils increased with the increase in concentration from 0.25 to 0.5%w/w. The similar results were also achieved by Kathirvelu and Raja (2015) who reported that 64.67% mortality of *Sitophilu. oryzae* L was due to the effectiveness of eucalyptus extracts applied on maize grains.

5.2 Effect of Treatment Concentrations on Organoleptic Quality of Stored Beans

Treatment concentration significantly influenced the grain odour evaluation score. The odour evaluation scores increased as the dosage rate increase. This implies that concentration influences the amount of odour emitted by a plant material. Both untreated and treated beans had odour score between the odourless and less offensive odour. In support to these findings other studies have reported that the application of plant leave powder on stored grains cause little offensive odour (Ogendo *et al*., 2004; Suleiman *et al.*, 2013; Masundire *et al*., 2014; Swarse *et al.*, 2017). In general, the mean score for odour attributes was below 2 (meaning less offensive odour). The likelihood of affecting the market value of the treated beans is also low, therefore, treating bean grains using insecticidal plant materials remains valid.

Similar to taste, the results indicated that the taste of stored beans where significantly affected by the insecticidal plant powder applied. Comparatively to control, the grains treated with insecticidal plant powder had the highest taste score. This is may be due the presence of active compounds in plant leaves such as azadirachitin which has bitter properties (Rajashekar *et al*., 2012). Similar results have been supported by the the study conducted by Boeke *et al*. (2001) and Zakariya *et al.* (2010) reported that the application of insecticidal plant materials had effect on taste of stored beans.

5.3 The Effect of Treatment Concentrations on Seed Viability Index of Stored Beans

Based on the findings of this study, there was significant decrease of seed viability index compared to initial value was recorded in grains treated with different concentration of eucalyptus and neem powder compared to those treated with shumba supermax (synthetic insecticide). Bean grains treated with synthetic chemical had the highest seed viability compared to untreated control and those treated with eucalyptus and neem powder. The highest germination percentage observed may be due to effectiveness of shumba super max dust to control storage diseases and storage insect pest which affect the germination capacity of stored beans. The minimum germination percent observed in untreated control may be due to deterioration of stored beans and fungal attack during germination process. Similar results from earlier studies (Nahar *et al*., 2009; Wani *et al*., 2014 and Musundire *et al.*, 2015) reported that application of insecticidal plant materials had positive effect on seed viability. Similar results were obtained in the study conducted by Kidane (2005) who reported that the decrease in seed germination of stored grains was due to fungal attack during germination process.

Moreover, the study findings indicate that eucalyptus and neem leave powder did not affect the seed viability when compared with seed viability of untreated beans. In general, the study found that the applied insecticidal plant leave powder had no significant effect on seed viability of stored beans.

CHAPTER SIX

6.0 CONCLUSSION AND RECOMMENDATIONS

6.1 Conclusion

The use of neem and eucalyptus powders as natural insecticides was effective and can be used to protect stored grains against storage insect pests. The insecticidal plant powder treatments at different concentration (10, 20, 30 g/kg) showed significant effect on odour and taste stored beans. The effects in score for both odour and taste increased with an increase of concentrations of plant powder. However, there was little offensive odour (Table 3.3) and little bitter taste (Table 3.4) of treated beans which virtually have no impact on home consumption and the likelihood could not affect the local market value of treated beans (Ogendo *et al.*, 2004; Swarse *et al.*, 2017). The application of insecticidal plant materials at different rates had no significant effect on seed viability compared to untreated beans (Wani *et al*., 2014; Musundire *et al*., 2015). Therefore, the insecticidal plant material can be used to treat beans to be stored until next season for planting and for consumption. The treated beans should be washed thoroughly with water to remove residues remained before used for home consumption.

6.2 Recommendations

In view of the findings from the current study, the following are recommended:

i. To increase the efficacy of these botanicals with minimal amount to be applied, further studies on their combination with other known botanicals is required.

ii. Further investigations are required to establish the possibility of penetration of these botanical treatments into stored grain and their potential effects on the nutritional content of the grains.

iii. Studies on the levels of residues remaining on treated food and their potential effects on human health when consumed should be evaluated before the use of these treatments are institutionally promoted as part of a sustainable insect pest management programme for farm level storage.

iv. Active ingredients in these botanicals need to be extracted and evaluated.

v. Based on the results of this study, extension officers and policy makers should rise awareness and formulate policies that will guide farmers in proper use of insecticidal plant materials in controlling storage insect pests as an alternative control method.

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APPENDICES

Appendix 1: Summary Table for analysis of variance (ANOVA) for mean percent mortality of adult bruchids in stored beans treated by neem and eucalyptus leave powder.

ANOVA table: % Mortality

Source of variation	Sum of Squares	df	Mean Square	F-ration	p-value
Treatment	146775.000	7	18346.875	1.006E3	.0001
Error	437.500	24	18.229		
Total	147212.500	31			

Appendix 2: Summary Table for analysis of variance (ANOVA) for mean odour score of stored bean grains treated by neem and eucalyptus leave powder

ANOVA table :Odour score

Source of variation	Sum of Squares	df	Mean Square	F	p-value
Treatment	4396.296	7	549.537	2.320E3	.0001
Error	528.704	2232	.237		
Total	4925.000	2239			

Appendix 3: Summary Table for analysis of variance (ANOVA) for mean taste score of stored bean grains treated by neem and eucalyptus leave powder

ANOVA table :Taste score

Source of variation	Sum of Squares	df	Mean Square	F	p-value
Treatment	6511.107	7	813.888	1.833E3	.0001
Error	990.893	2232	.444		
Total	7502.000	2239			

Appendix 4: Summary Table for analysis of variance (ANOVA) for mean germination percentage of stored bean grains treated by neem and eucalyptus leave powder.

ANOVA table:% Germination

Source of variation	Sum of Squares	df	Mean Square	F-ratio	p-value
Treatment	1763929.214	7	220491.152	8.592E3	.0001
Error	5542.786	216	25.661		
Total	1769472.000	223			