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EVALUATION OF *Icacina senegalensis* AND *Jatropha curcas* EXTRACTS FOR THE MANAGEMENT OF SWEET POTATO BEETLE *Cylas* spp. (COLEOPTERA: BRENTIDAE)

BY

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B.Sc. Hons. (AGRICULTURE)

MAY, 2012

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THEISIS FROM THE DEPARTMENT OF CROP AND SOIL SCIENCE SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF THE KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE (M.Sc.) DEGREE IN CROP PROTECTION (ENTOMOLOGY)

BY

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DECLARATION

I, EMMANUEL KOFI AMPONSAH, HEREBY DECLARE THAT, EXCEPT FOR OTHER PEOPLE'S WORK WHICH HAVE BEEN DULY ACKNOWLEDGED, THIS THESIS IS AS A RESULT OF MY OWN EFFORT AND IT HAS NEITHER IN PART NOR IN WHOLE BEEN SUBMITTED ELSEWHERE FOR THE AWARD OF A DEGREE.

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DEDICATION

I DEDICATE THIS PIECE OF WORK TO MY WIFE ANNA AND MY LOVELY DAUGTHER AKOSUA AGYEIWAA AMPONSAH.

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ABSTRACT

The adverse environmental effect of synthetic pesticides such as environmental pollution, destruction of beneficial insects, disruption of the ecosystem and contamination of harvested produces, have necessitated the call for environmentally safer, easily degradable and target specific insecticides. An experiment was therefore, conducted at the College of Agriculture Education, University of Education, Winneba, Mampong Ashanti Campus to determine the efficacy of different parts of *Icacina senegalensis* and *Jatropha curcas* leaf extracts for the management of sweet potato beetle (*Cylas* spp.). The treatments which were arranged in a Randomized Complete Block with three replications consisted of one time application of the following: 0.3 kg/ha fresh tuber extracts of *I. senegalensis* (T1), 0.3 kg/ha dried tuber extracts of *I. senegalensis* (T2) and 0.3 kg/ha of fresh leaves extracts of *I. senegaleensis* (T3) (0.18 g /1.5 L of water each per 6 m^2 plot). The others were two times application of 0.15 kg/ha of fresh tuber of *I. senegalensis* (T4), 0.15 kg/ha of dried tuber extracts of *I. senegalensis* (T5), 0.15 kg/ha of fresh leaves extracts of *I. senegalensis* (T6), (0.09 g/750 ml of water each per 6 m^2 plot). And one time application of (0.3 kg/ha each of fresh and dried leaves extracts of *J. curcas* respectively represented T7 and T8 (0.18 g/1.5 L water each per 6 m^2 plot). 30 ml of Dursban (chlorpyrifos) in 15 L of water represented T9 and T10 the control (no pesticide). The fresh leaf and tuber extracts of *I. senegalensis* (0.15 kg/ha and 0.3 kg/ha) and the chlorpyrifos treated plots had significantly fewer beetles at the base of the crop. The fresh leaf and tuber extracts of *I. senegalensis* (0.15 kg/ha and 0.3 kg/ha) and chlorpyrifos treatments also suppressed beetle infestation of the tubers, reduced tuber damage and increased marketable tubers. Extracts of the fresh

plant parts were more effective than extracts from the dried parts where damaged almost doubled and yield halved. Beetle population correlated positively with vine damage, tuber damage significantly ($p<0.05$) and negatively with marketable yield. It is therefore, recommended that sweet potato growers in the transitional ecological zone of Ghana can minimize tuber damage by *Cylas* spp. through application of fresh plant extracts of *I. senegalensis* during land preparation and one month after planting on the planting ridges.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Sweet potato (*Ipomea batatas* (L)) is grown in the warm parts of all continents. It has been reported that over 95% of sweet potato production is in developing countries where it ranks as the fifth most important tuber crop. From 2000 to 2003, world production of sweet potato increased from 125 to 145 million tonnes with China being the largest producer in the world. Uganda and Rwanda are the leading producers in Africa. (Martin *et al*., 2006).

Sweet potato is used primarily as food for humans and feed for livestock (Begue, 2008). According to Youdeowei (2002), the crop is cultivated primarily for the swollen tubers but the leaves are also used as vegetable. As industrial raw material, sweet potatoes are canned, dehydrated, or processed into starch, glucose, syrup and alcohol (Yayock *et al.*, 1988). In South America the juice of red sweet potatoes is combined with lime juice to make a dye for cloth. By varying the proportions of the juices, every shade from pink to purple to black can be obtained (Verrill, 1937).

Some major constraints to sweet potato production in Africa and other part of the world are beetles and viruses (Doku, 1969; Chalfant *et al.*, 1990; Lenne, 1991). The sweet potato beetle (*Cylas* spp.) can cause up to 70% crop loss (Youdeowei, 2002). Stoll (2000) reported that tubers infested by *Cylas* spp. are usually unmarketable and yield losses are

normally between 15 % and 30 % but can sometimes reach as high as 60- 97% depending on the season and cropping history of the field.

Three species of *Cylas*, namely *C. formicarius* (Fabricius), *C. puncticollis* (Boheman) and *C. brunneus* (Fabricius) attack sweet potato (CTA, 2003). *Cylas formicarius* is distributed globally and is the single most important insect pest of the crop. *C. puncticollis* and *C. brunneus* are known to occur only in Africa. The adult beetle feeds on potato leaves, base of vines and tubers and beetles complete their life cycle in the tubers (Sutherland, 1986a). The mature females lay eggs at the base of the vines or in the tubers. The larvae (white grubs) feed and tunnel through the tubers and vines. The tunnels provide entry points for fungi and bacteria which cause extensive rotting of the tubers accompanied by an offensive smell, making the tubers unfit for human and animal consumption. Feeding at the base of vines results in the thickening, malformation and cracking of tissues.

1.2 JUSTIFICATION OF THE STUDY

A number of strategies have been used for the control of *Cylas* spp. These include the use of resistant varieties, biological control and insecticides. Diaz and Grillo (1986) reported that high levels of adult beetle mortality (80-90%) were achieved in the laboratory when spores of *Beauvaria bassiana* isolate (JG-78) were applied to sterile soil. Swain (1943) also reported that under laboratory conditions, the beetle was parasitized by the nematode *Neoaplectana* spp.

Insecticides have long been used effectively against beetles. In the USA, soaking of cuttings in Phosmet 15 at 0.45 kg ai /378.5 litres of water was found to be an effective control measure against the beetle. The application of Permethrin 2 EC at 0.11 kg ai/ha at three - week intervals reduced losses (CTA, 2003). Martin *et al*. (2006) also stated that the beetle can be controlled by applying powdered tobacco leaves in 18 cm bands along the rows as well as on the plant bed.

Despite these successes, there are limitations to the use of insecticides in controlling beetles and these are increasingly being recognized. The main problems are pesticides resistance and negative impacts on non-target organisms including man and the environment (Singh *et al*., 2000, 2004). Many environmental problems such as development of resistance in pests to pesticides, resurgence of target and non-target pests, destruction of beneficial organisms and pesticides residue in host plants may be reduced through the proper use of active ingredients in some plants (Best and Ruthven, 1995; Singh and Saratchandra, 2002). The use of organochlorine and many other insecticides insecticides have been banned in developed countries and the alternative methods of insect pest control are being investigated (Klein and Dunkel, 2003).

The adverse environmental effects of synthetic pesticides have necessitated the call for the use of environmentally safer, easily degradable and target specific insecticides. As a result of these, efforts have been focused on plants or plant materials as potential sources of commercial insect control agents (Arnason *et al*., 1989; Han *et al*., 2006).

Icacina senegalensis (False yam) and *Jatropha curcas* (Jatropha) are shrubby plants which contain bitter toxic compounds, Icacinon and Icacinols and Jatropha curcasin respectively which virtually prevent pests and other disease-causing organisms from damaging the shrubs (Dalziel, 1948 and Wiesnhutter, 2003).

1.3. AIM OF THE RESEARCH

To develop a more sustainable, environmentally safer management technique for the potato tuber beetle

1.4. GENERAL OBJECTIVE OF THE STUDY

The research was conducted to determine the efficacy of extracts from *I. senegalensis and J. curcas* for the management of sweet potato tuber beetle

1.4.1 SPECIFIC OBJECTIVES

The specific objectives of the study were to determine the effect of the extracts of different parts of *I. senegalensis, Jatropha* leaf and chlorpyrifos on:

- Population of sweet potato beetle (*Cylas* spp.)
- Damage at base of vines
- Percentage and severity of tuber infestation
- Tuber yield

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and distribution of sweet potato

Sweet potato (*Ipomea batatas* (L) Lam.) belongs to the family Convolvulaceae. It was domesticated about 5000 years ago in tropical America (Austin, 1988). Austin (1988) stated that based on morphological characteristics of sweet potato and wild *Ipomea* species the crop originated in the region between the Yucatan Peninsula of Mexico and the Orinoco River in Venezuela. Molecular markers revealed the highest diversity in Central America, supporting the hypothesis that Central America is the primary center of diversity and most likely the center of origin of sweet potato (Zhang *et al.,* 1998).

Sweet potato is one of the world's important crops, after wheat, maize and rice in total production (Stathers *et al.,* 1999). Among the world's root and tuber crops, sweet potato is the second most important after white potato. Presently, the world's production of the crop is in excess of 130 million tonnes per annum. The bulk of the production occurs in Asia and China alone produces over 110 million tonnes per year which is equivalent to about 85%. In Africa, the important producers of sweet potato include Uganda and Rwanda; each country producing about 1% of the world's total crop. Sub-saharan Africa contributes only about 6% of the world production (Tweneboah, 2000).

2.2 Botanical description and some cultivars of sweet potato

Sweet potato, is a herbaceous perennial plant grown as an annual and propagated vegetatively using either storage roots or stem cuttings. Its growth habit is predominantly prostrate with a vine system that expands rapidly horizontally on the ground but some varieties are erect or semi-erect. The leaves are simple and spirally arranged alternately on the stem. The edge of the leaf lamina can be entire, toothed or lobed. The base of the leaf lamina generally has two lobes that can be almost straight or round. The shape of sweet potato leaves can be round, reniform, cordate, triangular, hastate, lobed and almost divided. The leaf colour can be green-yellowish, green or can have purple pigmentation in part or the entire leaf blade (Kays, 1985).

Sweet potato cultivars differ in their ability to flower. Under normal field conditions, some cultivars do not flower, others produce very few flowers, and others flower profusely. The flower is bisexual. Besides the calyx and corolla, they contain the stamens that are the male organs or androecium and the pistil that is the female organ or gynaecium. The calyx consists of 5 sepals, 2 outer and 3 inner, that are attached to the floral axle after the petals dry up and drop. The corolla consists of 5 petals that are fused forming a funnel, generally with lilac or pale purple limb and with reddish to purple throat. The androecium consists of five stamens with filaments that are covered with glandular hairs and that are partly fused to the corolla. The gynaecium consists of a pistil with a superior ovary, two carpels, and two locules that contain one or two ovules (CIP *et al*., 1991).

According to Addo-quaye *et al.* (1991), the three main cultivars of sweet potato grown in West Africa are white, red and yellow and that their classification is based on flesh and skin colour. The white is the sweetest among the cultivars cultivated in Ghana. Some of the improved varieties released by the Crop Research Institute include Otoo, Ogyefo, Asantompona, Nhyira and Faara (CSIR-CRI, 1998).

2.3 Growth requirements of sweet potato

Sweet potato is grown between latitudes 48°N and 40°S and at altitudes ranging from sea-level to 3000 m. Its growth is maximum at temperatures of about 25°C but its growth is retarded when temperatures fall below 12°C or exceed 35°C (CTA, 2003). Sweet potato is a sun-loving crop but it can also tolerate a 30-50% reduction of full solar radiation. It grows best with a well-distributed annual rainfall of 600-1600 mm during the growing season. Dry weather condition favours the formation and development of the edible roots. Sweet potato is relatively drought tolerant and can produce good crop yield under conditions too dry for other crops (Horton and Gregory, 1989). However the crop cannot withstand long periods of drought and the yield is considerably reduced if drought occurs at planting or during root initiation. The crop can be grown on poor soils with little fertilizer. Sweet potatoes are very sensitive to aluminum toxicity and will die about 6 weeks after planting if lime is not applied at planting in this type of soil (Woolfe, 1992).

The crop can be grown on a wide range of soil types, but a well-drained, sandy loam with clayey subsoil is considered ideal (Macgraw, 1999). It cannot withstand waterlogged soil condition. According to Woolfe (1992) and Ahn (1993), sweet potatoes are grown on a

variety of soils, but well-drained light and medium textured soils with a pH range of 4.5-7.0 are more favourable for the plant. Flooding shortly before harvest may result in rottening of storage roots in the soil or during storage. But according to Kay (1989), the optimum soil pH for sweet potato is 5.6 - 6.6 but it grows well even in soils with a relatively lower pH of about 4.2. It is sensitive to alkaline or saline soils. Kay (1989) reported that sweet potato cannot form tuberous roots under water logged conditions although the root hairs may grow. This is attributed largely to oxygen starvation and may also be associated with the production of toxic gases such as carbon dioxide, ethylene and ethanol within the root tissues.

2.3.1. Land preparation

Good land or soil preparation involves removal or incorporation of crop debris and any vegetation that may compete with the crop, and deep manual or mechanical cultivation. Cultivation aims to turn over the topsoil and loosen the compacted soil below, to achieve a good tilth for the preparation of mounds or ridges to provide a uniform medium where storage root growth is not impeded. This can be achieved by thorough ploughing and harrowing, depending on soil condition. Plant mulches, manures or other additives such as lime, gypsum or rock phosphate, which have been applied to the surface, are mixed into the soil for greater effect. Loosening up the soil increases the oxygen content, which favours the development of microorganisms (Youdeowei, 2002). Mounds are preferred by farmers and these are made entirely with hand tools. In some areas, broad raised beds are used. On deep, well-drained soil, planting may be done on flat fields. Ridges should be

oriented along contours on sloping land, to maximize rain infiltration and minimize erosion. Ridges are usually raised to about 30-45 cm high, but may be higher in wet areas to facilitate drainage. They are usually between 90 and 120 cm apart (Youdeowei, 2002).

2.4 Major Pests and diseases of sweet potato

Sweet potato is a host to a number of pests and diseases. Some of the pests include sweet potato beetle (*Cylas* spp.), variegated grasshopper, sweet potato butterflies, clearwing moth, sweet potato stemborers, tortoiseshell beetle, red spider, cricket and whiteflies (Gabriel, 2000). According to Otoo *et al*. (1998), sweet potato beetle is the most notorious insect pest of the crop. Some of the diseases of sweet potato include bacterial stem and root rot, leaf and stem scab, *Fusarium* wilt, sweet potato mottle virus disease and soil rot (Ames *et al*., 1996).

2.5 Biology and distribution of sweet potato beetle

The different species of sweet potato beetle have similar life cycles. The adult female lays eggs singly in cavities excavated in vines or in most cases inside the storage roots. The egg cavity is sealed with a protective, gray plug. The developing larvae tunnel into the vine or storage root. Pupation takes place within the larval tunnels. Because the female beetle cannot dig, its finds storage roots in which to lay its eggs by entering through soil cracks.

Adults of all species may be conveniently distinguished by the shape of the distal antennal segment, which is filiform (thread-like, cylindrical) in males and club-like in females. The males have larger eye facets than the females. At optimal temperatures of 27–30°C, *C. formicarius* completes development in about 33 days. The longevity of the adult is 2.5 to

3.5 months and females lay between 100 and 250 eggs within this period. *C. puncticollis* has a total development time of about 32 days, whereas *C. brunneus* takes 44 days. Adults of *C. puncticollis* live for an average of 100 days whereas *C. brunneus* lives for about 60 days. *C. puncticollis* females lay 90–140 eggs in their lifetime, whereas *C. brunneus* females lay 80–115 (Ames *et al*., 1996). *Cylas puncticollis* is one of the most important pests of sweet potato in tropical Africa, notably Uganda, Rwanda, Kenya and Cameroon. *Cylas brunneus* is known from West and Central Africa and some East Africa countries including Rwanda, Burundi and Kenya. The two species are both found attacking sweet potatoes in East and West Africa (Hill, 1983). *Cylas formicarius* is also a destructive pest of sweet potato common in the tropical and subtropical regions and occurs in several African countries. Adult beetles feed on leaves, the underground storage roots and the base of vines of the plant. The adults prefer the storage roots but can also live on the stem and leaves at the early stage of the plant growth when the tubers are not formed. They lay eggs on vines and leaves and the grubs feed in the stem or the leaf and pupate inside the vines. Beetle damage increases as the crop remains unharvested. In Kenya, where farmers practice piecemeal harvesting, losses averaged about 10%. Pest damage usually continues during storage, therefore infested tubers cannot be stored for a long time (Allard *et al.,* 1991).

2.6 Description of the three species of the genus *Cylas*

Three species of the genus *Cylas* are pests of sweet potato and are commonly called sweet potato beetles. The three species—*Cylas formicarius*, *C. puncticollis*, and *C. brunneus*—are found in Africa. *Cylas formicarius* is found in Asia and some parts of the Caribbean. The elongated ant-like adults of the three species can be distinguished from each other. *Cylas puncticollis* is the easiest to distinguish because the adult is black and relatively larger than the other two species. *Cylas formicarius* has a bluish black abdomen and a reddish brown thorax. The adults of *Cylas brunneus* are small and without a uniform colour. The eggs are shiny and round in all the three species. The larvae are white and curved, and the pupae are also white in colour (Ames *et al*., 1996)

2.7 Methods of managing sweet potato beetles

The development of insect pest management strategies for sweet potato has long been based on the eventual replacement of insecticides with alternative methods (Boiteau, 2010). According to VanderZaag (2010), environmentally sustainable potato production requires reduced dependence on the use of synthetic pesticides. Consumers are increasingly becoming concerned about the health and quality of produce and the protection of the environment, and thus are changing their purchasing patterns. Farmers are responding with reduced and more efficient use of pesticides by means of use of more environmentally friendly chemicals, superior application equipment, scouting, training, and increased communications. Studies on the impact of insects on potato production

reveal substantial variation between estimates according to sites and years (Stemeroff and George, 1983; McLeod and Tolman, 1987).

Insect pest management in potato production begins prior to planting the crop (Boiteau *et al*. 1995; Miller and Hopkins 2008) and the control methods include: cultural practices compatible with natural processes: vegetation management to farvour natural enemies; release of biological control agents; and the use of approved insecticides. There are no good or bad control methods, conventional or alternative methods, but rather a collection of methods ranging from preventive to curative (Wyss *et al*., 2005; Zehnder *et al*., 2007).

2.7.1. Cultural control Practices

2.7.1.1. Soil Health

Soil health is often a neglected aspect of insect pest control. If a key objective of ecologically based control is to prevent insect pest outbreaks before corrective action is required, researchers and specialists must improve their understanding of the relationship between insect pests and the health of the soil (Bioteau, 2010). Phelan *et al*. (1996) found that plants grown in organically managed soils reach a natural mineral balance that provides them with tolerance or resistance to insect pests. Boiteau *et al*. (2008b) observed a shift in the timing of peak populations of Colorado potato beetles but no significant change in abundance when comparing organic and mineral fertilizers in soils with short history of organic production. Similarly, Alyokhin and Atlihan (2005) and Alyokhin *et al*. (2005) offered partial support for the hypothesis on potato by showing that populations of

Colorado potato beetle on manure amended potato plots were lower and took longer to develop than on chemically fertilized plots. Nitrogen (N) and potassium (K) can influence host plant–insect interactions and pest damage levels by changing the chemical characteristics of a crop. This has the potential to influence the feeding and or ovipository behaviour of insect pests. Nitrogen increases the protein and starch content of sweet potato (Bartoloni, 1982; Li, 1982) and influences the levels of triterpenoids in other plants (Gershenzon, 1991). Protein and starch are important nutritional requirements of insects, whilst triterpenoids are known to influence the ovipository behaviour of sweet potato beetles (Nottingham *et al*. 1988).

Fallow vegetation can influence soil fertility levels and can also potentially reduce pests' incidence by disrupting the life cycle either through a break in crop rotation or by the release of allelopathic chemicals.

2.7.1.2. Crop Rotation

Bioteau (2010) reported that potato fields should be sited at locations unsuitable for the development of insect pests. Cultural practices that modify the agricultural landscape to reduce the size of crop fields increase the size of hedgerows and increase the distance between crops and sources of colonizing pests can each separately or together have a substantial negative impact on the dispersal and establishment of many potato insect pests. For example, crop rotation is central to the management of the Colorado potato beetle that overwinters as adults in potato fields. Rotation away from the previous year's potato crop is effective against potato pests (Boiteau *et al*., 2008a). Weisz *et al*. (1996), Blom and

Fleischer (2001) and Boiteau (2005) also reported that Colorado potato beetle densities are reduced when the crop is rotated but its use is limited by the lack of access to sufficient land within a farm over a rotation period. Delanoy *et al*. (2003) stated that this method can be used on its own but approved or registered insecticides will be needed to control larvae later in the season if rotation distances are short.

2.7.2. Exclusion Methods

2.7.2.1. The use of physical barriers

According to Bioteau (2010), when the crop cannot be rotated due to land constraints, exclusion methods can be employed. Boiteau and Vernon (2001) reported that lining trenches near potato farms with plastic can serve as barriers to potato beetles that may migrate into the potato field. Beetles can move on clean plastic mulch at an angle, but once the plastic is coated with fine soil particles, this becomes impossible. Trenches with walls sloping at an angle greater than 46° will retain an average of 84% of all adults caught under field conditions. Kuepper (2003) also stated that exclusion of the beetles can be achieved through the use of "floating row covers," whereby a thin fabric spun from synthetic material which allows air and moisture to travel through it, while preventing access of pest species to the plants.

The use of uninfested planting material, especially vine tips, removal of volunteer plants and crop debris or proper sanitation, flooding the field for 24 hours after harvest, timely planting and prompt harvesting to avoid a dry period, removal of alternate hosts also help in minimizing infestation on the field (Ames *et al*., 1996).

2.7.2.1. The use of resistant varieties

According to Ames *et al*. (1996) and Tingey and Yencho (1994), sweet potato varieties with high level of resistance are not available. Some varieties have low to moderate levels of resistance. Others escape beetle damage because their storage roots are produced deep in the soil or because they mature early and can be harvested to reduce attack, for instance New Kawogo genotype (Stevenson *et al*., 2009). The development of insect resistant varieties is confronted with numerous methodological challenges, and an unfortunate linkage between undesirable crop qualities and susceptibility to other insects or diseases (Decker, 1962). In spite of new breeding technologies, the time required to develop resistant varieties is also substantial.

2.7.3. Vegetation Management to Enhance Natural Enemies

The different management practices of the potato crop can affect the abundance and richness of soil Collembola and mites (Carter and Noronha, 2007). The benefits of vegetation enhancement can only be measured as a long term investment and must be balanced against negative effects. For example, shelterbelts created around sweet potato fields enhance populations of predators but also facilitate the successful overwintering of insect pests such as the Colorado potato beetle (Boiteau, 2010). Noncrop vegetation can increase the abundance of natural enemies in crops, because of the provision of resources such as pollen and nectar as well as shelter (Landis *et al*., 2000; Wackers *et al*., 2005). Danne *et al*. (2010) reported that native cover crops also increase the abundance of some potential pest species. Native plants, therefore, even though may have the potential to

increase abundance of beneficial invertebrates that assist in pest control, need to be used carefully to ensure that they do not increase local pest problems. However, cover crops are not necessarily always effective in enhancing pest control. Natural enemies that are increased by cover crops might not target pests (Baggen and Gurr, 1998; Olson and Wackers, 2007). Similarly, Bone *et al.* (2009) reported that under dry conditions cover crops might not establish successfully and hence cannot provide adequate resources for beneficial arthropods. They can also promote the presence of pests and diseases and compete with crops for moisture to decrease yield (Snapp *et al.*, 2005; Bone *et al*., 2009).

2.7.4. Biological Control of *Cylas* spp.

The extensive use of insecticides in cropping systems has negative effects on non-target organisms and can suppress the population of organisms that can be used for biological pest control. With the introduction of new agrochemicals, the assessment of their effect on the survival and beneficial capacity of natural enemies is essential in order to identify selective insecticides for incorporation into integrated pest management programs (Paul and Thygarajan, 1992). Insecticides may kill the biological control agents or change several other features of their biology without killing the individuals. The sub-lethal effects which include the longevity and fecundity, developmental rate and sex ratio, predation rate, and mobility of predators have not been extensively studied (Moura *et al*., 2006).

However micro-organisms have been used with varying levels of success. The fungi *Beauvaria bassiana (*Bals.-Criv) and *Metarrhizium anisopliae* (Metchnikoff) and the nematodes *Heterorhabditis* spp. and *Steinernema* spp. have been identified as promising

biological control agents for sweet potato beetle. These fungi attack and kill adult beetles, whereas the nematodes kill the larvae (Ames *et al*., 1996). When *M. anisopliae* attack, its spores germinate on the body of the host insect under conditions of prolonged high humidity. The fungus penetrates the insect and uses its internal body contents as substrate for proliferation. After killing the host, the fungus emerges through the joints in the insect exoskeleton, appearing first as a white growth. When spores are formed, the fungus turns green. Spores emerging from the dead host spread to new hosts by wind or water. *Beauveria bassiana* attacks stemborers, leaf folders, and bugs, and it has been confirmed as pathogen of sweet potato beetles and the sweet potato butterfly.

Like other fungi, it requires conditions of prolonged high humidity for the air-or waterborne spores to germinate. The fungus invades the soft tissues and body fluids of the host and grows out of the body to sporulate. Insects which are attacked are covered with a powdery white substance. Other pathogens that may play a role in the biological control of pests in sweet potato fields include the fungi *Hirsutella* spp. and *Nomuraea rileyi* (Farlow). The nematodes *Heterorhabditis* spp. and *Steinernema* spp. can also be used as biological agents against sweet potato beetle (Ames *et al*., 1996).

2.7.5. Managing sweet potato beetles with Insecticides

Chemical pesticides today constitute a major and critical input in the production of agricultural and horticultural crops all over the world. Although chemical pesticides have been used in achieving significant increase in crop yields, they constitute serious ecological and human health hazards. Instances of application hazards and residual toxicity to human beings are well known and documented. But, even more important, and serious, are the environmental hazards (Hoddy, 1991)

Insecticides have traditionally been used in the reduction of sweet potato tuber damage by insects (Schalk *et al*., 1991). Despite the fact that insecticides are a valuable tool used in pest management systems, many drawbacks such as the development of insect resistance exist (Metcalf, 1994). The extensive use of insecticides in cropping systems also has negative effects on non-target organisms, including the reduction of their effectiveness as biological control agents (Rezac *et al*., 2010). The organophosphates, phosmet and methyl parathion, are recommended for use in a mandatory spray programme as it occurred in southern Louisiana for the control of sweet potato beetle. In addition carbaryl, a carbamate, and bifenthrin, a pyrethroid, have received an emergency exemption for use on sweet potato in Louisiana since 2001 (USEPA 2005a). In the USA, soaking of cuttings in phosmet 15 at 0.45 kg ai/378.5L of water was found to be an effective control measure against beetle infestation that occurred by mechanical transfer. The application of permethrin 2EC at 0.11 kg ai/ha at three weeks intervals also reduced crop losses. (CTA, 2003).

2.7.6. The use of botanicals to control pests

There are problems of pesticides resistance and negative impacts on non-target organisms including man and the environment (Singh *et al*. 2000, 2004). Many environmental problems such as development of resistance in pests to pesticides, resurgence of target and non-target pests, destruction of beneficial organisms and pesticides residue in host plants may be reduced after proper use of the active ingredients present in the plants (Singh and Saratchandra, 2002; Best and Ruthven, 1995). The use of organochlorine insecticides has been banned in developed countries and the alternative methods of insect pest control are being investigated (Klein and Dunkel, 2003).

The adverse environmental effects of synthetic pesticides have necessitated the call for the use of environmentally safe, easy degradable and target specific insecticides. As a result of these, efforts have been focused on plants or plant materials as potential sources of commercial insect control agents (Han *et al*., 2006). The uses of plant materials in pest control has become an important alternative to the use of synthetic insecticides and this is because plants are rich sources of chemical compounds with various medicinal and insecticidal properties (Arnason *et al*., 1989).

2.7.5.1 Methods and Mode of action of some botanicals

Botanical insecticides are prepared in the form of the crude plant material, extracts or resins. The crude plant material is usually ground into a powder and marketed full strength or diluted with a carrier. Rotenone, pyrethrum flowers, sabadilla seeds, ryania stems and neem seeds are often ground into powdered form. Simple methods of preservation by

drying and heat-treating the seeds were the most common practices used to reduce the pest population (Singh *et al*., 2004). During early days, plants were used in various forms to keep the pests away from the agricultural field**.** This is because many of these plants chemicals possess larvicidal, pupicidal and adulticidal activities while most act as repellants, ovipositional deterrents and antifeedants against both agricultural pests and medically important insect species (Mordue, 2004; Rajasekharreddy and Usha Rani, 2010). Some Citrus species have been reported as a source of botanical insecticides because they contain secondary metabolites that show insecticidal activity against several coleoptera and diptera organisms (Salvatore *et al*., 2004; Shrivastava *et al*., 2010) and lepidoptera species (Sahayaraj, 1998). Limonoids which are extremely bitter chemicals and present in citrus seeds act as antifeedants or antagonize ecdysone action in many lepidopteran species (Klocke and Kubo, 1982).

Botanical 'tea' solutions (*Omusasie*) are traditionally used as insecticides in Kenya; it is prepared by crushing hot pepper and bitter leaves, mix them with soapy water and soot, then leave it for three days just stirring occasionally before sieving it. The liquid is diluted in 1:1 with water and then sprinkling or spraying on the infested sweet potato plants. Ash can be sprinkled onto the sweet potato plants and surrounding soil to help kill crawling insects.

Azadirachtin, the active ingredient in neem, is an ecdysone antagonist that disrupts insect moulting (Tomlin, 2000). Neemazal (Azadirachtin) has been found to be slightly harmful to Geocoris bugs (Myers *et al.*, 2006), Harmonia beetles, and *Mallada lacewings* (Qi *et al*.,

2001). Podisus bugs had, however, slightly reduced survival and reproduction (Vin˜uela *et al.*, 2000). Acetamiprid, the active ingredient of Mospilan, is an agonist of the nicotinic acetylcholine receptor and affects the synapses in the insect central nervous system (Tomlin, 2000).

Most plant species used for plant protection exhibit an insect deterrent rather than insecticidal effect. It indicates that in some way those compounds inhibit normal development in insects. They act in different ways viz. insect growth regulators (IGR), feeding deterrents, repellents and confusants. Antifeedant and repellant activities have been evaluated for some of the plants. A true antifeedant gives insect the opportunity to feed on the plants, but the food intake is reduced until the insect dies from starvation (Saxena, 1987).

Feeding deterrence is perhaps the most studied mode of action for plant derivatives used for insect pest management. Feeding deterrent is a compound that once probed by the insect, causes it to stop feeding and starve to death. Many compounds showing this activity are terpenes and most have been isolated from medicinal plants native to Africa and India. The extracts of the plants greatly reduced feeding regardless of the method of treatment. This indicates that the extract contained chemicals, which deter feeding. In all plants tested, more feeding was observed on air-dried leaves than on fresh leaves. Probably the components of the extract, which deter feeding, were volatilized during drying (Singh and Saratchandra, 2005). The reduced feeding on fresh leaves could be either due to direct toxic action of the fresh extract on the larvae and or to the presence of feeding deterrent as exhibited by the *Lantana camara* leaf extract, which is both toxic and antifeedant.

Antifeedant activity of *Myllocerus viridanus* on *Terminalia arjuna* leaves was reported by Sharma *et al.* (2002). More than 75% mortality was exhibited at 24 h when the leaf squares were sprayed after introduction of the larvae. Singh and Thangavelu (1996) reported influence of neem compound on the growth and development of immature forms of the uzifly, an important parasite of tasar silkworm. It acts on insects by repelling them, inhibiting feeding, and by disrupting their growth, metamorphosis and reproduction.

Repellents, on the other hand drive the insects away after exposure to the plant without necessarily feeding. The use of plants as repellents is very old but has not received the necessary attention for proper development. Compounds having bad odour or irritant effects are used. Garlic and peppers are most common plants under this group. Garlic powder has been used to show away rodents. Further, the use of fennel (*Foniculum vulgare*), rue (*Ruta graveolens*) and eucalyptus (*Eucaliptus globolus*) among other aromatic plants to repel cloth moths are very common (Singh and Saratchandra, 2005).

2.9. Description of *Icacina senegalenesis* and *Jatropha curcas*

False yam *(Icacina senegalensis)* which belongs to the family Icacinaceae is a perennial shrub and variable in form. The plant has glabrous or pubescent erect leafy shoots from a large, underground fleshy tuber. The aerial stems are light green, and may reach about 1 m in height. The leaves are simple, ovate or obovate, pointed or rounded at the apex, 5-10 cm long and 4-7 cm broad, light green when young, but becoming leathery and dark green on the upper surface and dull green on the lower part. The flowers are inconspicuous, usually white or cream and pedunculate, ascending or erect, corymbose cymes, collected into a

terminal leafless panicle, or the lower peduncles arising from the axis of reduced leaves. The calyx is in five divisions, the pointed lobes are bright green; the corolla is composed of 5 narrow, white or creamy-white petals, covered with silky hairs on their outside surface. The tubers are greyish in colour with a thin skin enclosing white flesh, which is usually speckled with yellow spots that correspond to bundles of xylem. They contain bitter toxic compounds, Icacinon and Icacinols which prevent pests and other disease causing organisms from feeding and hence the plant not been a host to pests and diseases causing organisms. The plant usually grows in the wild but seldom cultivated. It is occasionally planted in Africa and it is reportedly propagated by pieces of tubers and planted before the wet season (Cerighelli, 1919; Irvine, 1930; and Dalziel 1948).

The jatropha plant (*Jatropha curcas* L.) is a shrub with a maximum height of about five meters. It originated in Central America and is currently found throughout the world particularly in the tropics. It belongs to the family Euphorbiaceae and can survive a wide range of climate and soil. Jatropha produces plum-size fruit with two or three oleiferous seeds. The seed and oil yields vary greatly according to origin and growth conditions. Dry conditions increase the oil content of the seeds. In Cape Verde, per-hectare yields of between 780 and 2,250 kg of seeds are harvested (Münch and Kiefer, 1986). The seeds and leaves are toxic because of the presence of curcacin and phorbol esters. Because of the toxic and bitter substances, the plants are not eaten by livestock. Jatropha plant is generally highly resistant to pests and as results of its insecticidal and molluscicidal properties (Wiesenhütter, 2003).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of experimental site

The study was carried out from June 2010 to January 2011 at the College of Agriculture Education, University of Education, Winneba, Mampong Ashanti Campus. The area is located between latitude 07^{o} and 08^{0} N of the equator and 457.5 m above sea level. (Meteorological Service Department, 2002).

3.2 Climate soil and vegetation of the area

Mampong-Ashanti is in the transitional zone which is found between the rain forest in the south and Guinea savanna belt in the north. The major rainfall occurs from March to July whiles the minor rainfall starts around September and ends in Novermber. The dry season starts from December and ends in February. The annual rainfall of the area ranges between 1270 mm and 1524 mm. The mean monthly rainfall is around 91.2 mm and the mean monthly temperature ranges from 25ºC to 32ºC while relative humidity is usually75 and 80 % in the morning and it usually drops to 65-70 % in the afternoon. (Meteorological Service Department, 2002).

The soil at the project site is a well drained sandy loam with a thin layer of organic matter. It is a type of savanna forest ochrosol formed from the Voltarian sandstone of Afram plains. The pH of the soil is between 6.0-6.8 (Adu, 1992). The vegetation of the area is

predominantly *Cyperus rotundus* (L), *Centrosema* spp. and *Panicum maximum* (Jacq) and some shrubs.

3.3 Land Preparation

The area for the experiment was demarcated in August, 2010. The land was cleared with machete and debris were raked off. The land was ploughed and harrowed after two weeks and demarcated into blocks and plots. The blocks and plots were separated by one meter wide alleys. The area used for the experiment was 8 m x 39 m (312 m^2) and each plot was 3 m x 2 m. Four ridges were prepared on each plot with a hoe. The ridges were 2 m long, 0.75 m wide and about 45 cm high.

3.4 Planting materials and planting

Vine cuttings of "Ogyefoo" sweet potato variety obtained from the Crops Research Institute of the Council for Scientific and Industrial Research, Fumesua in Kumasi, was used in the experiment. The vines were cut into pieces of about the same length with 2-3 nodes. The planting distance was 75 cm between rows and 30 cm within rows.

3.5. Preparation of botanical extracts and application rates

3.5.1 Preparation of fresh aqueous extracts of *Icacina senegalensis* and *Jatropha curcas*

Fresh leaves of *Icacina sengalensis* about 40 cm from the base of the shrub were collected and 0.09 g and 0.18 g of the leaves were weighed with an electronic balance and mixed

separately with 100 ml and 200 ml of water and blended. The blended extracts were then diluted with 650 ml and 1300 ml of clean water respectively. The same rates of the fresh tuber of the plant (*I. senegalensis*) were also weighed with electronic balance and similarly processed.

Fresh leaves of *Jatropha curcas* were plucked and 0.18 g was weighed with an electronic balance and mixed with 200 ml of clean water and blended with an electronic blender. The broth was then made up to 1500 ml extract.

3.5.2 Preparation of aqueous extracts of dried *Icacina senegalensis* and *Jatropha curcas* parts

The fresh leaves and fresh tuber of the *Icacina senegalensis* and the fresh leaves of *Jatropha curcas* were chopped and dried under shade separately for five days. The dried samples were milled with mechanical miller into powder. Then 0.09 g and 0.18 g of each of the powdered samples was weighed with an electronic balance and the extract prepared as previously described for the fresh tissues.

3.5.3 Application of treatments

Application of the treatments was done using a one and half litre (1.5 L) hand pump fitted with hollow cone nozzle. The treatments were applied onto the experimental plots during the preparation of the ridges and again to the base of the crop (vines) one month after planting the vines. The application rates for the aqueous extracts of the botanicals were 0.18 g/1.5 L of water per 6 m^2 plot (0.3 kg/ha) and 0.09 g/750 ml of water (0.15 kg/ha).

The one time application treatments (0.3 kg/ha) were done during the preparation of the ridges whilst the two times application (0.15 kg/ha) were done on the apices of the ridges during preparation of the ridges and one month after vines establishment. Chlopyrifos (Dursban) was the standard synthetic insecticides against which the botanical extracts were compared.

3.6 Treatments and experimental design

Ten treatments were tested in the experiment. They were arranged in a randomized complete block design and each treatment was replicated three times. The treatments were:

- 0.3 kg/ ha of *Icacina senegalensis* fresh tuber extract applied once (ISFT1)
- 0.3 kg/ha of *Icacina senegalensis* dried tuber extract applied once (ISDT1)
- 0.3 kg/ha of *Icacina senegalensis* fresh leaves extracts applied once (ISFL1)
- 0.15 kg/ ha of *Icacina senegalensis* fresh tuber extracts applied twice (ISFT2)
- 0.15 kg/ha of *Icacina senegalensis* dried tuber extracts applied twice (ISDT2)
- 0.15 kg/ha of *Icacina senegalensis* fresh leaves extracts applied twice (ISFL2)
- 0.3 kg / ha of *Jatropha curcas* fresh leaves extract applied once (JCFL1)
- 0.3 kg/ ha of *Jatropha curcas* dried leaves extract (JCDL1)
- Chlorpyrifos (Dursban) 30 ml/15 litres of water.
- Control

3.7 Agronomic practices applied

3.7.1 Watering

During the first two weeks after planting, watering was done because there were no rains and the vines needed water to sprout. Watering was done in the morning and evening using watering can. Twelve litres of water were applied per ridge at each watering. After the second week, watering was done once a day in the morning whenever necessary.

3.7.2 Weed control

The first and second weeding (with a hoe and hand picking) were done at the third and sixth weeks after planting since the vines had not yet spread out. The third and fourth weeding involved clearing the paths around each plot. The vines were redirected to keep the alleys clear whenever necessary.

3.7.3 Fertilizer application

NPK (15-15-15) was applied to the crop at rate of 400 kg/ha (60 kg/ha each of Nitrogen, Phosphorus and Potassium) to boost growth of the plant. The application was done by band placement method three weeks after planting. Each plant received 10 g (1.5 g each of N, P and K) of the fertilizer.

3.8 Sampling and data collection

Six plants on the two middle rows (per plot) were selected and tagged for data collection.

3.8.1 Number of cracks at the base of vines

Six weeks after planting, the number of cracks at the base of vines was counted and repeated every week for a period of six weeks.

3.8.2. Number of beetles at the base of vines

From the sixth week after planting, the number of beetles at the base of vines were handpicked and counted and repeated every week for a period of six weeks and at harvest.

3.8.3. Number of damaged vines at maturity

Before harvesting, number of vines damaged at the base was counted and recorded.

3.8.4. Mean number of tubers infested by *Cylas* spp.

Number of tubers infested was determined by visual observation of tubers. Tubers with either feeding damage or punctures on the outer skin were considered infested.

3.8.5 Percentage of tubers infested per plot

Percentage of tubers infested were determined by counting the number of infested tubers and expressed as a percentage of the total number of tubers produced per plot. A tuber was considered infested if it had characteristic dark spots, typical symptoms of beetle penetration and feeding.

3.8.6. Mean number of beetles in infested tubers

Number of beetles in infested tubers was determined by slicing the infested tubers on a white nylon material using a kitchen knife and the beetles retrieved from each tuber were counted and recorded.

3.8.7 Mean percentage utilizable portion of infested tuber

The percentage of undamaged portion (utilizable portion of infested tubers) was determined by slicing the infested tubers into damaged and undamaged portion. The weight of the utilizable portion (portion that can be used in preparation of starch and animal feeds) was expressed as percentage of the total weight of the tuber.

3.8.8 Severity of damage to tubers

The severity of damage to tubers was assessed using the rating scale described by Sutherland (1986b).

Rating	Description
1	0% damage
2	1-10 % damage
3	11-25% damage
4	26-50 % damage
5	51-75% damage
6	>75% damage

Tubers were separated into different categories depending on the percentage of the external signs of infestation. The damage within each plot was then expressed as weighted mean.

3.8.9 Marketable yield

Clean tubers with crown diameter greater than 25 mm were determined using venier calipers and were classified as marketable. They were then weighed with top pan balance and the weight in kg / 3 m^2 expressed in tonnes per hectare.

3.8.10 Unmarketable yield

Tubers with less than 25 mm crown diameter and those infested by beetles were classified as unmarketable expressed in tonnes per hectare.

3.9 Data analysis

Experimental data collected were subjected to Analysis of Variance (ANOVA) using GenStat discovery edition 3 version 7.22 (2008) and when the ANOVA was significant, the means were separated using LSD. Count data were transformed using the square root transformation before the ANOVA.

3.9.1 Correlation analysis

Correlation analysis was done for beetle population against damaged vines, damaged tubers, marketable tubers and unmarketable tuber.

CHAPTER FOUR

4.0 RESULTS

4.1 Different extracts of *Icacina senegalensis, Jatropha curcas* and chlorpyrifos on number of cracks at the base of sweet potato vines

Table 4.1 shows the effect of different extracts of *Icacina senegalensis, Jatropha curcas* and chlorpyrifos on number of cracks at the base of sweet potato vines from the 6th week after planting (WAP) to the 11th WAP. Neither the botanical extracts nor the the synthetic insecticides (Dursban) has any clear cut effect on cracking at the base of the vines from the 6th to the 10th weeks of planting. However, at the 11th WAP, all the treated plots had significantly fewer cracks at the base of the vines on the planting ridges than the control plots.

Table 4.1. Effect of different extracts of *Icacina senegalensis, Jatropha curcas* and chlorpyrifos on mean number of cracks at the base of sweet potato vines

Treatments	Mean number of cracks at the base of the sweet potato vines					
	6 WAP	7 WAP	8WAP	9WAP	10WAP	11WAP
0.3 kg/ha ISFT1	2.3	5.0	5.7	5.7	7.3	9.3
0.3 kg/ha ISDT1	2.0	7.0	8.7	9.3	9.6	10.0
0.3 kg/ha ISFL1	2.0	3.7	4.3	6.3	7.0	9.0
0.15 kg /ha ISFT2	2.3	3.0	5.0	6.7	9.3	10.1
0.15 kg /ha ISDT2	1.3	6.7	7.0	7.3	8.3	9.7
0.15 kg /ha ISFL2	1.0	3.7	6.0	7.3	8.3	9.3
0.3 kg/ ha JCFL1	1.0	6.0	6.0	6.3	8.0	9.3
0.3 kg /ha JCDL1	1.0	5.7	7.0	7.3	7.3	9.7
Chlorpyrifos	0.7	6.3	8.7	9.7	10.0	10.0
Control	3.0	5.7	9.0	10.0	10.0	12.3
LSD (0.05)	1.4	2.3	2.9	2.6	2.3	2.2
CV (%)	28.6	25.9	24.8	19.8	15.9	13.0

4.2. Effect of *Icacina senegalensis, Jatropha curcas extracts* and chlorpyrifos on number of sweet potato beetles at the base of potato vines

The results of the number of beetles at the base of the sweet potato vines from the 6th WAP and at harvest are presented in Table 4.2. At 6 WAP the plots treated with different rates of fresh leaves and fresh tuber extracts of *I. senegalensis* (0.15 kg and 0.3 kg/ha) had significantly ($P<0.05$) fewer number of beetles at the base of the sweet potato vines compared to the chlopyrifos and dried extracts treated plots. The highest number of beetles was found on the untreated plots. Similar results were obtained from the 7 to 9 WAP. The number of beetles counted on ridges treated with 0.3 kg/ha each of dried tuber extracts of *I. senegalensis* and dried leaf extracts of *J. curcas* separately were not significantly different from each other but each treatment recorded significantly lower numbers than the control plots. At 10 WAP, all the treated plots had significantly lower number of beetles than the untreated plots. At harvest, the number of beetles on plots that received 0.3 kg/ha ISDT1 did not differ significantly from the number on the control plots and plots treated with two times application of 0.15 kg/ha of ISDT but were significantly more than the other treated plots. The lowest beetle numbers were counted on plots treated with 30 ml chlorpyrifos in 15 L of water, two times application of 0.15 kg/ha of ISFL and 0.3 kg/ha each of JCFL1 and JCDL1. Plots treated with fresh leaves extracts of *I. senegalensis* both at ridge preparation and one month after vines establishment had the lowest total number of beetles at the base of the sweet potato vines but did not differ beetles counted on plots treated with 0.3 kg/ha each JCFL1 and ISFT1 did not differ significantly. The control plots had

significantly (P<0.05) more beetles at the base of the sweet potato vines than the rest of the treated plots.

Table 4.2 Effect of *Icacina senegalensis, Jatropha curcas extracts* and chlorpyrifos on number of sweet potato beetles at the base of potato vines

Treatments	Mean number of beetles at the base of sweet potato vines						
	6WAP	7 WAP	8WAP	9 WAP	10WAP	At Harvest	Total beetles counted
0.3 kg/ha ISFT1	0.7	1.2	1.4	1.2	0.9	1.6	3.0
0.3 kg/ha ISDT1	1.3	1.9	1.9	1.0	1.1	3.1	4.6
0.3 kg/ha ISFL1	0.9	1.0	1.0	0.7	0.7	1.4	2.4
0.15 kg/ha ISFT2	0.9	0.7	1.1	1.0	0.7	1.5	2.5
0.15 kg/ha ISDT2	2.2	2.2	2.4	0.7	0.7	2.8	4.9
0.15 kg/ha ISFL2	0.7	0.7	1.1	0.7	0.7	1.3	2.2
0.3 kg/ ha JCFL1	1.5	1.1	1.3	0.7	1.1	1.3	2.9
0.3 kg/ha JCDL1	1.9	1.9	1.9	0.9	0.9	1.1	3.7
Chlorpyrifos	1.2	1.1	1.0	0.7	0.7	1.1	2.6
Control	3.1	3.4	3.5	1.6	1.5	3.4	7.1
LSD (0.05)	0.2	0.1	0.1	0.2	0.4	0.4	0.3
CV (%)	9.9	5.3	3.3	11.6	22.8	11.6	4.4

4.3. Tuber infestation and number of beetle as influenced by different botanicals and chlorpyrifos treatments

The treated plots produced significantly ($P<0.05$) fewer numbers of infested tubers compared to the control plots (Table 4.3). Application of 0.3 kg/ha of ISFL1, two times application of 0.15 kg/ha ISFL2 and the same rates of the fresh tuber extracts were not significantly different from each other in respect of infested tubers but were, however, significantly different from the other plant extracts treated plots. Plots treated with chlorpyrifos produced significantly fewer number of infested tubers than the different rates of the dried tuber extracts of *I. senegalensis.* Similarly, fewer beetles were counted in the infested tubers from plots treated with 0.3 kg/ha each of ISFL1, ISFT1, and two times application of 0.15 kg/ha of ISFL. These were not significantly different from tubers on plots treated with 30 ml chlorpyrifos in 15 L of water but significantly lower than tubers from the control plots with respect to beetles in infested tubers. With respect to the percentage of damaged portion of infested tubers, application of 0.3 kg/ha of ISFL1, two times application of 0.15 kg/ha each of ISFL and ISFT and the chlorpyrifos produced significantly ($P<0.05$) lower damaged portion than the other treated plots. There was no significant ($P>0.05$) difference between the control plots and the plots treated with 0.3 kg/ha of *Jatropha curcas* extracts in terms of total percentage of infested tubers. Application of 0.3 kg and two times application of 0.15 kg/ha ISFL and chlorpyrifos also produced significantly ($P<0.05$) lowest percentage infested tubers. Apart from the control plots, the application of 0.3 kg/ha each of ISDT1, JCDL1 and two times application of 0.15

kg/ha of ISDT produced significantly higher number of infested tubers than the other treated plots.

Table 4.3. Tuber infestation and number of beetles as influenced by different extracts of *I. senegalensis, J. curcas* and chlorpyrifos.

Treatments	Mean number of infested tubers per plant	Mean number of beetles per tuber	Mean % infested tubers per plot
0.3 kg/ha ISFT1	3.0	3.6	44.1
0.3 kg/ha ISDT1	8.3	6.3	75.9
0.3 kg/ha ISFL1	2.3	3.4	24.1
0.15 kg/ha ISFT2	3.3	4.3	36.5
0.15 kg/ha ISDT2	8.0	6.9	78.4
0.15 kg/ha ISFL2	3.0	3.5	27.4
0.3 kg/ ha JCFL1	4.0	4.8	47.9
0.3 kg/ha JCDL1	6.7	5.7	79.9
Chlorpyrifos	5.3	4.0	29.1
Control	12.3	9.1	86.4
LSD (0.05)	1.9	0.5	7.8
CV (%)	19.5	5.6	8.6

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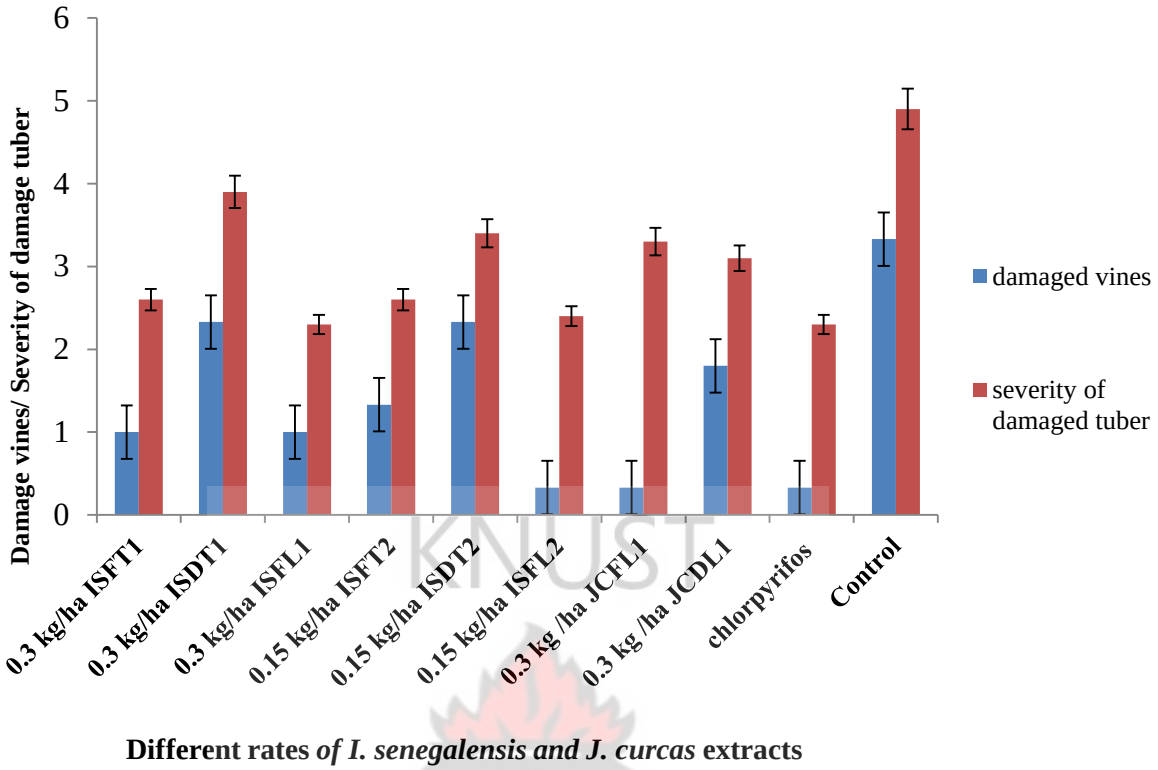

Fig.4.1. Effect of different extracts of *Icacina senegalensis, Jatropha curcas* extracts and chlorpyrifos on number of vines damaged and severity of damage to tubers by *Cylas* spp.

4.4. Different extracts of *Icacina senegalenis, Jatropha curcas* extracts and chlorpyrifos on the number of vines damaged and severity of damage to tubers by *Cylas* spp.

Figure (4.1) shows the number of damaged vines and severity of damage to tubers by the sweet potato beetle. The difference in vine and tuber damage between chlorpyrifos, ISFT, JCFL, JCDL and ISFL treated plots were not significant but were all significantly lower than in the control plots.

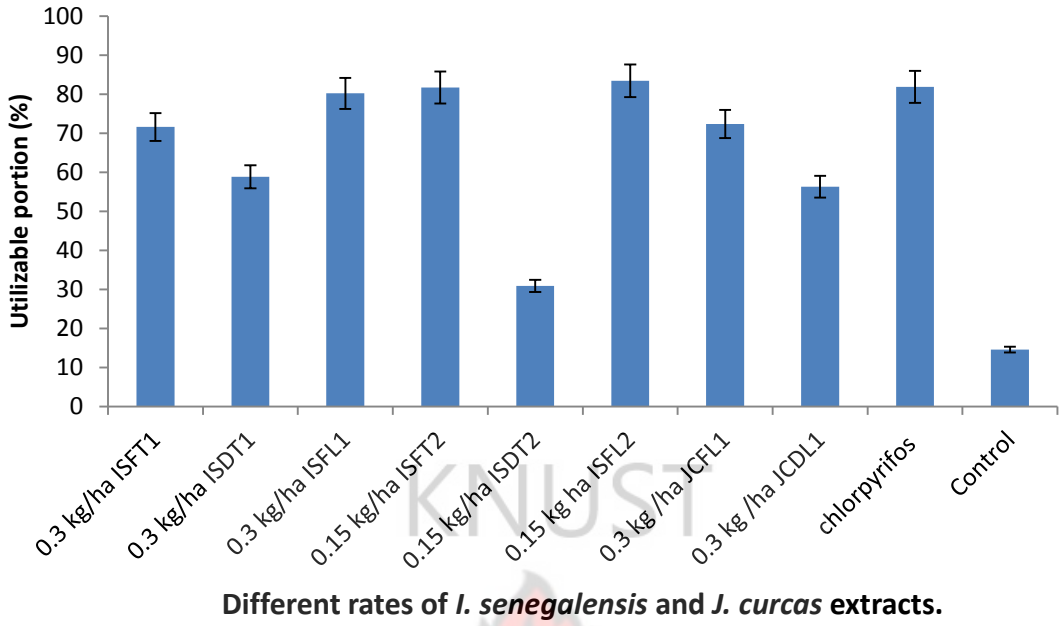

Fig. 4.2. Utilizable portion of tuber attacked by *Cylas* spp. as affected by different pesticide

4.4. Utilizable portion of tubers attacked by *Cylas* spp. as affected by *Icacina senegalensis, Jatropha curcas* leaf extracts and chlorpyrifos.

Fig.4.2 shows the utilizable (undamaged) portion of tubers attacked by *Cylas* spp. as affected by *I. senegalensis, J. curcas* extracts and chlorpyrifos. The largest undamaged portions of the attacked tubers were observed on plots treated with ISFL1 at 0.3 kg/ha and on plots treated with two times application of 0.15 kg/ha each of ISFT, ISFL and application of chlorpyrifos at 30 ml in 15 L of water. These were not significantly ($P > 0.05$) different from each other but each was significantly different from the other treated plots and the control plots which had tubers with smallest undamaged portions.

4.6. Effect of different extracts of *Icacina senegalensis, Jatropha curcas* and chlorpyrifos on yield of sweet potato

The marketable tubers produced on plots treated with ISFT at different rates and application of 0.3 kg/ha ISFL did not differ significantly ($P<0.05$) but were significantly larger than the yield from the control plots (Table 4.4). Different rates of ISFT and chlorpyrifos effect did not also differ significantly ($P>0.05$). Marketable tubers from the plots treated with ISDT and JCDL1 were similar to the control plots. The other treated plots produced significantly more marketable tubers than the control plots. With respect to unmarketable tubers, two applications of ISFL at 0.15 kg/ha did not differ significantly from plots treated with different rates of ISFT and chlorpyrifos but where significantly less than the control plots. The unmarketable tubers on plots treated with dried plant extracts did not differ significantly from tubers produced from the control plots. (Table 4.4).

Table. 4. 4. Effect of different extracts of *Icacina senegalensis, Jatropha curcas* and chlorpyrifos on yield of sweet potato

Treatments	Mean marketable yield (t/ha)	Mean unmarketable yield (t/ha)
0.3 kg/ha ISFT1	6.30	2.52
0.3 kg/ha ISDT1	2.68	5.82
0.3 kg/ha ISFL1	2.84	6.04
0.15 kg/ha ISFTI2	5.68	3.28
0.15 kg/ha ISDT2	2.02	7.39
0.15 kg/ha ISFL2	6.67	2.00
0.3 kg/ha JCFL1	3.01	5.47
0.3 kg/ha JCDL1	2.15	6.22
Chlorpyrifos	5.37	2.96
Control	1.67	5.11
LSD (0.05)	1.04	1.33
CV (%)	15.80	16.50

4.7. Correlation between beetle population and damage and yield of sweet potato

Beetle population correlated positively with vine damage, tuber damage and unmarketable yield and were significant ($p < 0.05$) and negatively with marketable yield as shown in Table 4.5

Table 4.5. Correlation between beetle population and damage and yield of sweet potato

Correlation	Correlation co-efficient (r)	Probability
Beetle population versus damaged vines	0.742*	0.031
Beetle population versus tuber damage	0.803*	0.021
Beetle population versus marketable yield	-0.967*	0.011
Beetle population versus unmarketable yield	0.917*	0.013

*Significant ($p < 0.05$)

CHAPTER FIVE

5.0 DISCUSSIONS

5.1. Different extracts of *Icacina senegalensis, Jatropha curcas* and chlorpyrifos effect on number of cracks and *Cylas* spp. at the base of sweet potato vines.

The differences in number of cracks at the base of vines might be due to the degree moistening of the surfaces of the ridges during the application of the treatments which might have reduced cracking at the bases of vines in the treated plots compared to the control plots. Probably these extracts also contributed to binding the soil particles thereby improving the texture of the soil and thus minimizing cracks on those plots. It has been reported by Teli and Salunkhe (1994) that cracking around tubers occur when soils dry out under low rainfall conditions which can influence beetle accessibility to tubers. At 7 WAP cracks observed at the base of vines on ridges treated with two times application of 0.15 kg/ha of ISFT, and ISFL1 were not significantly different from each other but significantly lower compared to the control. The trend did not differ from the 8 to 9 WAP. Similarly, at the 11 WAP all the treated plots did not differ significantly but were significantly lower than cracks on the control plots. The variations in cracking on the planting ridges from the 8 to 9 WAP may due to the enlargement of the tubers during that growth period which might have enhanced cracking in the root zone as it has been reported by Bouwkamp (1983) that sweet potato tubers actively enlarge during the 8- 16 weeks growing period.

Differences in the number of beetles counted on the ridges at the various growing stages of the crop can be attributed to differences in concentrations of the extracts and probably different insecticidal effects of the plant extracts used. From the 6 to 10 WAP, the treated plots had significantly fewer beetles at the base of the potato vines compared to the control plots. This might be due to the different botanicals used and the different number of applications. Many plant chemicals have been reported to have larvicidal, pupicidal and adulticidal activities, most being repellants, ovipositional deterrents and antifeedants against both agricultural pests and medically important insect species (Salvatore *et al*., 2004; and Shrivastava *et al*., 2010). The numbers of beetles counted on plots treated with dried plant extracts were significantly more than beetles counted on plots treated with fresh plants parts of *I. senegalensis* and *J. curcas* respectively from the 6 to 9 WAP. According to Singh and Saratchandra (2005), drying of botanicals can cause volatilization of the active ingredients or components of the extracts responsible for repelling the targeted insects hence more beetles observed on plots treated with dried botanical extracts than the fresh extracts of the botanicals.

5.2 Number of infested tubers, number of beetles in infested tubers and percentage of damaged portion of infested tubers as influence by different extracts of botanicals and chlorpyrifos.

The presence of more beetles observed on the control plots and also the numerous cracks observed on the ridges at the base of the sweet potato vines during the growing period of

the crop might have served as point of entry for the beetles which might have caused more infestation of tubers. Teli and Salunkhe (1994) had reported cracking around tubers as they enlarge and when soils dry out under low rainfall conditions which can influence beetles' accessibility to the tuber. The number of infested tubers produced on plots treated with dried extracts of the botanicals was significantly smaller than tubers on the control plots but more than plots treated with the fresh plant extracts. These differences on one hand were due to larger number of beetles recorded on plots treated with extracts from dried plant parts during the growing stage of the crop. On the other hand the differences could be attributed to volatilization of the pesticidal components of the extract, during drying of the botanicals (Singh and Saratchandra, 2005).

5.3 Plant extracts and chlorpyrifos effect on yield of sweet potato

Plots treated with different rates of ISFL, ISFT and chlorpyrifos produced fewer unmarketable tubers because fewer vines were damaged by fewer beetles. Also fewer cracks observed on those impeded the accessibility of the beetles to the tuber zone of the crop to cause infestation, hence, fewer unmarketable tubers on those plots compared to plots treated with dried extracts of the botanicals. These plots produced significantly ($P<0.05$) more marketable tubers than the other treated plots. The larger number of unmarketable tubers on the control plots could be due to the more cracks observed on the ridges which might have served as entry point for the beetles to the tubers. Not protecting the sweet potato crop from insect attack was not agronomically sensible. This did not differ from the report by Schalk *et al*. (1991) that insecticides have traditionally been the primary

defense in reducing root damage caused by insects to sweet potato. Mason *et al*. (1991), using a topical bioassay, found that sweet potato beetles were better controlled with chlorpyrifos and parathion than carbaryl or endosulfan. Mordue (2004) also stated that many plant species are known to possess insecticidal properties; although only a few of these have been exploited commercially. The compounds in some botanicals have a number of useful activities like toxicity, repellence, feeding and oviposition deterrence and insect growth regulator activity. The fresh extracts of *I. senegalensis* and *J. curcas* extracts probably suppressed beetle infestation and reduced tuber damaged by sweet potato beetles by being toxic, acting as a repellant or oviposition deterrence. The reduced tuber feeding on fresh leaves and tuber extracts treated plots could either be due to direct toxic action of the extract on the larvae at the base of the vines and or the presence of feeding deterrent in the fresh plant extracts. Also probably the fresh plant extracts was both toxic and antifeedant or the plants extracts possessing some repellant effect to the beetles. Sharma *et al.* (2002) had reported that many plant extracts like *Lantana camara* are both toxic and antifeedant to some pests like *Myllocerus viridanus* (Fab).

CHAPTER SIX

6.0 CONLUSION AND RECOMMENDATION

6.1 CONLUSION

The plots treated with the different rates of the fresh leaves and tuber extracts of *Icacina senegalensis* (0.15 kg/ha and 0.3 kg/ha) and the chlorpyrifos had the smallest beetle population during the growing period, lower vine damage at the base and fewer beetles in infested tubers.

Application of the different rates (0.15 kg/ha and 0.3 kg/ha each) of fresh leaves extracts of *Icacina senegalensis* and 30 ml of chlorpyrifos in 15 L water produced tubers with the lowest level of infestation of 24 %, 27 % and 29 %, respectively.

Plots treated with the various rates of fresh leaf extracts (0.15 kg/ha and 0.3 kg /ha), 0.3 kg/ha of fresh tuber extracts of *Icacina senegalesis* and the chlorpyrifos produced tubers with larger utilizable (undamaged) portions and the lowest damage severity.

The largest mean marketable yield was produced from the plots treated with two times application of 0.15 kg/ha ISFL (6.67 t/ha), followed by plots treated with 0.3 kg/ha ISFT1 (6.30 t/ha) and two times application of 0.15 kg/ha of fresh tuber extracts of *Icacina seneglensis* (5.68 t/ha). These plots also had the lowest unmarketable tubers together with the chlorpyrifos treated plots.

Extracts of the fresh plant parts were more effective than extracts from dried parts where damage almost doubled and yield halved in the plots treated with extracts from the dried parts.

6.3 Recommendation

Both the fresh tuber and fresh leaf extracts of the *I. senegalensis* could be used as an alternative to inorganic pesticides in *Cylas* spp. management on sweet potato. It is however, recommended that the leaves should be used in order to allow the shrub to survive.

Research should also consider integrating the plant extracts with other management practices such as hilling up, mulching of planting beds to minimize beetle accessibility to the tuber.

Further research should consider varying the rates and time of application of the leaf extracts.

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APPENDICES

***** Analysis of variance *****

Variate: DAMAGE_VINES

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	1.7167	0.8583	3.47	
Rep.*Units* stratum					
TRT	9	28.0000	3.1111	12.58	<.001
Residual	18	4.4500	0.2472		
Total	29	34.1667			

***** Analysis of variance *****

Variate: mean_marketable_yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.0850	0.0425	0.12	
Rep.*Units* stratum					
TRT	9	101.0457	11.2273	30.72	<.001
Residual	18	6.5778	0.3654		
Total	29	107.7085			

***** Analysis of variance *****

Variate: %_of_total_no_tubers_infested_on

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	53.97	26.99	1.29	
Rep.*Units* stratum					
TRT	9	16344.80	1816.09	87.08	<.001
Residual	18	375.40	20.86		
Total	29	16774.17			

***** Analysis of variance *****

Variate: NUMBER_OF_CLEANED_TUBERS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	1.4000	0.7000	1.12	
Rep.*Units* stratum					
TRT	9	202.5333	22.5037	35.95	<.001
Residual	18	11.2667	0.6259		
Total	29	215.2000			

***** Analysis of variance *****

Variate: NUMBER_OF_INFESTED_TUBERS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	4.267	2.133	1.77	
Rep.*Units* stratum					
TRT	9	274.967	30.552	25.30	<.001
Residual	18	21.733	1.207		
Total	29	300.967			

***** Analysis of variance *****

Variate: NUMBER_OF_BEETLES_IN_INFESTED_TUBERS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	21.80	10.90	1.05	
Rep.*Units* stratum					
TRT	9	13367.87	1485.32	142.57	<.001
Residual	18	187.53	10.42		
Total	29	13577.20			

***** Analysis of variance *****

Variate: NUMBER OF BEETLES AT THE BASE OF VINES AT HARVEST

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.03227	0.01613	0.35	
Rep.*Units* stratum					
TRT	9	20.59149	2.28794	49.10	<.001
Residual	18	0.83874	0.04660		
Total	29	21.46249			

***** Analysis of variance *****

Variate: NUMBER OF BEETLES IN INFESTED TUBERS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.21436	0.10718	1.28	
Rep.*Units* stratum					
TRT	9	91.43145	10.15905	120.93	<.001
Residual	18	1.51209	0.08401		
Total	29	93.15791			

***** Analysis of variance *****

Variate: NUMBER BEETLES AT THE BASE VINES AT THE 5TH WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.02174	0.01087	0.53	
Rep.*Units* stratum					
TRT	9	15.51760	1.72418	84.64	<.001
Residual	18	0.36668	0.02037		
Total	29	15.90601			

***** Analysis of variance *****

Variate NUMBER BEETLES AT THE BASE VINES AT THE 6TH WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.000902	0.000451	0.07	
Rep.*Units* stratum					
TRT	9	18.970310	2.107812	327.32	<.001
Residual	18	0.115912	0.006440		
Total	29	19.087124			

***** Analysis of variance *****

Variate: NUMBER BEETLES AT THE BASE VINES AT THE 7TH WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.005141	0.002570	0.86	
Rep.*Units* stratum					
TRT	9	17.239476	1.915497	641.27	<.001
Residual	18	0.053767	0.002987		
Total	29	17.298384			

***** Analysis of variance *****

Variate: NUMBER BEETLES AT THE BASE VINES AT THE 8TH WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.00034	0.00017	0.01	
Rep.*Units* stratum					
TRT	9	2.47703	0.27523	23.61	<.001
Residual	18	0.20982	0.01166		
Total	29	2.68719			

***** Analysis of variance *****

Variate: NUMBER BEETLES AT THE BASE VINES AT THE 9TH WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.06206	0.03103	0.76	
Rep.*Units* stratum					
TRT	9	1.64252	0.18250	4.46	0.003
Residual	18	0.73715	0.04095		
Total	29	2.44173			

***** Analysis of variance *****

Variate: unmarketable_yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.2040	0.1020	0.17	
Rep.*Units* stratum					
TRT	9	91.2074	10.1342	16.97	<.001
Residual	18	10.7507	0.5973		
Total	29	102.1621			

***** Analysis of variance *****

Variate: Total beetles counted

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.00870	0.00435	0.17	
Rep.*Units* stratum					
TRT	9	63.67347	7.07483	280.94	<.001
Residual	18	0.45329	0.02518		
Total	29	64.13546			