

STUDIES ON THE SUITABILITY OF *Parkia biglobosa*  
(Jacq.) [AFRICAN LOCUST BEAN] FOR THE  
DEVELOPMENT OF *Sitophilus zeamais* Motschulsky  
(COLEOPTERA: CURCULIONIDAE).

BY

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## DECLARATION

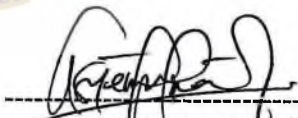
I do hereby declare that this thesis with the exception of references to other people work which I have duly cited, this work is entirely my own research and has not been presented elsewhere for the award of a degree.

  
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## DEDICATION

This work is dedicated to my late Dad Alhaji Abdulrahman Mustapha Ali (May his gentle soul rest in perfect peace, Amen) and my Mum Hajia Abbo Mustapha whom through them I came to be.



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## ABSTRACT

Maize is an important staple food crop in Ghana and is cultivated throughout the country. The Guinea savanna zone in the Northern region, which is fast becoming a major production zone, is also the natural ecological zone of *Parkia* plants. Some insect pests, such as *Sitophilus zeamais* are a serious threat to maize production in Ghana. These insects appear to have adapted to and survive on some wild host plants. They may therefore emigrate from these alternative hosts to preferred hosts when the crops are planted in the field. The objective of this study was to investigate the suitability of *Parkia biglobosa* for the development of *S. zeamais* and also to determine whether *S. zeamais* adults would exhibit any preference for *Parkia* substrates when given a choice. A comparative study of the development of *S. zeamais* on *Parkia* seeds, pulps, pods and maize showed that the weevil does not reproduce at all on *Parkia* substrates under both field and laboratory conditions. Mean developmental period on maize under controlled conditions was significantly ( $P < 0.05$ ) shorter (41.2 days) than under ambient environmental conditions (47.0 days). The mean weight of adults (3.4mg) under controlled conditions was, however, not significantly different ( $P > 0.05$ ) from what was obtained under ambient environmental conditions (2.8mg). The mean

number of eggs laid on maize under controlled conditions was significantly ( $P < 0.05$ ) higher (114.5) than under ambient environmental conditions (94.75) and no eggs were laid on *Parkia* seeds, pulp and pods. In free-choice tests, significantly ( $P < 0.05$ ) more weevils were recorded on maize than on *Parkia* substrates under both sets of conditions. Comparative study on survival of *S. zeamais* on *Parkia* seeds, pulp, pods and maize variety Volta local showed that survival of the weevils stabilized with time on maize but high mortality was recorded on *Parkia* seeds, pulp and pods under both sets of conditions. More weevils survived on *Parkia* seeds, pulp and pods in an environmental chamber in the laboratory than under the field conditions. From this, no conclusion can be drawn that *Parkia* pods, pulp and seeds may act as alternate hosts for *S. zeamais* and investigation needed to be undertaken to determine the actual factors responsible for the unsuitability or unacceptability of *Parkia biglobosa* as a host for *S. zeamais*. It is suggested that a better understanding of the biology and behaviour of *S. zeamais* in relation to *Parkia* pods, pulp and seeds will assist in the development of improved management practices for the control of this pest and so reduce heavy losses caused by this pest both in the field and storage.

## CHAPTER ONE

### 1.0. INTRODUCTION

A major shift in global cereal demand is underway and by the year 2020, the demand for maize in developing countries will surpass the demand for both wheat and rice (CIMMYT, 2004). This shift will be reflected in a 50 % increase in global maize demand from its 1995 level of 558 millions to 837 millions tonnes by 2020. Maize requirement in the developing world alone will increase from 282 million tonnes in 1995 to 504 million tonnes in 2020. An annual maize demand in sub-Saharan Africa is expected to double to 52 million tonnes by 2020 (CIMMYT, 2004).

In Ghana about 400,000 hectares of land is under cultivation of maize (*Zea mays* L.). Maize production averaged around 375,000 tonnes per annum during 1970–1985 (Rouanet, 1992) and has increased from 553,000 metric tonnes in 1990 to 961,000 metric tonnes in 1993 (Owusu-Akyaw, 1991; PPMED, 1994). Estimated production for 1995 was 1.4 million metric tonnes and currently estimated to be 1,800,000 metric tonnes (Morris *et al.*, 1999 ; WFP, 2002 ; SRID, 2005).

Maize is a staple cereal crop in many parts of Africa and it has replaced many traditional starchy foodstuffs, such as sorghum and millets, particularly in South Africa, Malawi, Zimbabwe and Kenya, and in considerable sections of Angola,

Zambia, Tanzania, Mozambique, Cameroon, Benin, Togo, Ghana, Nigeria and Egypt (Purseglove, 1992). It is comparable in significance to rice in Asia and wheat in the Middle East (Kim,1987). In Ghana, maize is one of the most important cereal crops (Rouanet,1992) which is cultivated throughout the country, but yields are highest on well-drained, deep, fine soils. It is an important source of carbohydrate and forms about 90 – 95 % of the total calorie intake of the coastal savanna people (Baba, 1994; Dankyi *et al.*, 1995). Insect pests are among the key factors contributing to low yield of maize and they are central to many, if not one of the major problems facing maize production today (CIMMYT,2001). Worldwide more than 200 species of insect pests have been recorded on maize (Purseglove, 1992). The most common among these are *Sitophilus zeamais* Motschulsky, *Sitophilus oryzae* (L.), *Rhyzopertha dominica* (F.), and *Prostephanus truncatus* Horn (NRI, 1996).

Post-harvest losses to storage insect pests, such as maize weevils, *Sitophilus zeamais* have been recognized as an increasingly important problem in Africa (Markham *et al.*,1994). *S. zeamais* is one of the most serious storage pests of maize in the tropics (Bosque-Perez and Buddenhagen,1992). The insect infests the ripening crop in the fields before harvest and multiplies further during storage (Caswell,1962 ; Hills,1983 ; Kim and Kossou, 2003). Current food losses during storage are estimated to be about 200 million tonnes and worth US\$20 billion (Bengston,2005). In Africa, losses of cereal crops have been estimated to be about

10-80% (Youdeowei,2005). In Ghana, out of the total annual harvest of 250 – 300,000 tonnes of maize, about 20 % were lost to insect pests and 15 % of this was attributed to maize weevils (Prempeh,1971;Youdeowei,1989). In some cases total losses can occur (Obeng-Ofori and Amiteye,2005). Losses to food grains caused by storage insects are serious a threat to food security (Ayertey,2002). Therefore, post harvest production management is critical in ensuring food security (Sefa-Dedeh and Senanu,1995).

*Parkia biglobosa* (Jacq.) Benth, also called African locust bean, belongs to the family Leguminosae and the sub-family Mimosoideae (Hopkins,1983). It is cultivated in areas with between 800 and 1500 mm of annual rainfall, 1400 and 2100 mm of potential evapotranspiration, and is generally associated with a dry season-of five to seven months. It occurs on mid-toposequence position on deep soils and sometimes, through farmers protection, on well–drained soils in flood plains and riparian sites. It is absent from depressions where soil drainage is impeded (Hall *et al.*,1997). The species naturally occurs in the dry forests of the Sudano- Guinean savanna to the Southern border of the Sahel ecozone on the 600 mm isohyets (ICRAF,2004). In Ghana, *P. biglobosa* is found mainly in the Northern part of the country and its distribution conforms to common environmental factors throughout its range (Shao, 2002).

*Parkia biglobosa* is an important alternate host of some insects. Setamou *et al.*(2000a) recorded several generations of corn ear-borer, *Mussidia nigrivenella* Rogonots on *P. biglobosa*. Emerging *M. nigrivenella* populations from pods of the natural host plant (*P. biglobosa*) constitute an important source of infestation to nearby maize field (Setamou *et al.*, 2000b). A weevil and pyralid moth were also observed on the pods; the moth eats both pulp and seeds (Hopkins,1983 ; ICRAF,2004). *Sitophilus. zeamais* has been observed on *Parkia* pods several times (Ayertey, personal communication).

The major difficulties associated with the management of storage pests are the influence of alternate hosts as important sources of re-infestation to maize fields. Many species of stored insect pests appear to have adapted to, and survive on some wild host plants. They may therefore emigrate from these alternative hosts to preferred hosts when the crops are planted in the field. In Northern Nigeria, the bruchid, *Bruchidius atrolineatus* (Pic) has been recorded from wild legumes, including *Vigna triloba* Walp, at different times during the dry season when cowpea, its principal host is not normally grown (Prevett,1961 ; Booker,1967). In Ghana, it was reported that larvae of *Eldana saccharina* Walker remain in the stubble of sugar-cane after harvest and re-infest new shoots. Thus, the stubble serves as a reservoir for re-infestation by stem-borers (Kumar,1984). *Sitophilus zeamais* has also been recorded on several wild host plants such as chestnuts, acorns and sunflowers (William and Floyd,1971 ; Delobel and Grenier,1993).

Therefore, the problems caused by alternate hosts as a reservoir of insect pests cannot be overemphasized, as they promote infestation and reinfestation, thus making management of insect pests difficult. Many studies have been done on the development of *S. zeamais* on cereals but little or no work has been done on wild hosts, especially *P. biglobosa* as an alternate host. This study is an attempt to investigate the suitability of *P. biglobosa* as an alternate host/breeding substrate for *S. zeamais*.

### **1.1. General Objectives**

The general objective of this work was therefore to investigate the suitability of *P. biglobosa* pods, seeds and pulp as breeding substrates for *S. zeamais*.

### **1.2. Specific objectives**

The specific objectives of this study are therefore as follows:

- (i) To evaluate the survival of *S. zeamais* on *Parkia* and maize substrates.
- (ii) To examine relative preference of *S. zeamais* for *Parkia* and maize substrates.
- (iii) To evaluate the oviposition of *S. zeamais* on *Parkia* and maize substrates.
- (iv) To determine developmental period of *S. zeamais* on *Parkia* and maize substrates.
- (v) To determine mean weight of adults emerging from *Parkia* and maize substrates.

## CHAPTER TWO

### 2.0.LITERATURE REVIEW

#### 2.1. The Maize (*Zea mays* L.)

##### 2.1.1. Taxonomy, distribution and ecology

Maize (*Zea mays* L.) is a monocotyledon of the Gramineae family adapted to both tropical and temperate agro-ecological zones and is the only species in the tribe Maydeae (Purseglove,1992). The tribe Maydeae consists of annual or perennial herbs. There are eight genera, of which five are in the old world, extending from India, through South eastern Asia to Australia. The name maize is derived from an Arawak-carib word “Mahiz”(Purseglove,1992). It is also known as ‘Indian corn’ and in America it is simply called ‘corn’

Maize is one of the most important staple crops in the world (CIMMYT,2004). It is the most widely distributed, and most important in the United States of America which produces half the world’s total maize, occupying double the area than any other crop (Purseglove,1992). Maize was introduced into Africa from its native Mesoamerica in the 16<sup>th</sup> century (CIMMYT,2004). It has become an important source of carbohydrate in 16 African countries; a total of 5,080,000 metric tonnes of the crop were produced in these countries between 1986 and 1988, and the percentage increase in its use as food and feed 74.9 and 17% respectively (CIMMYT,1990).

A wide range of environmental conditions affect maize growth. It is essentially a crop of warm countries with adequate moisture. It requires about 450 – 600 mm of rainfall during its growing season (Purseglove,1992). An optimum temperature of 32 – 35°C is ideal for its growth (Downey,1971). Maize production in Ghana is affected by several factors of which moisture availability, high soil temperature and low soil nitrogen are important (Mintah,1998). Depending on agro-ecological location, there may be one or two cropping seasons of maize in Ghana (Boateng, 1996). There are two rainy seasons in the important production areas of the forest and forest–savanna transition zones. These are the major and minor seasons. Rainfall in the major season begins in March/April and ends in August while the minor season begins in August/September and ends in November/December. With supplemental irrigation, three crops per year are obtainable (NARP,1993; Edwards,1995). The dry spell in August allows for harvesting of the major season crop and land preparation for the minor season. In Northern parts of Ghana, covering the Guinea savanna areas, the unimodal rainfall pattern spanning over five month from May to September provide for only one crop (Boateng, 1996).

### **2.1.3. Economic Importance**

Most of the maize crop is used in the countries in which it is grown and only about 10 percent enters the world trade and of which the United States supplies about 60 percent (Purseglove,1992). Maize is used for three main purposes:(i)as a staple human food, particularly in the tropics.(ii) as feed for livestock, particularly in

temperate and advanced countries, providing over two thirds of the total trade in feed grains. (iii) as a raw material for many industrial products.

Maize is prepared and consumed in a multitude of ways. It is usually ground and pounded, and the meal may be boiled, baked or fried (Purseglove,1992). The whole grain may be boiled or roasted and it may be fermented. Maize meal is cooked with water to provide a thick mush or dough, which is the commonest method of eating it in Africa. Corn bread is made by mixing the meal with wheat flour. Mature cobs are roasted and eaten. Cornflakes made out of maize are used as breakfast cereals (Purseglove, 1992). Maize constitutes an important part in the diet of rural and urban Ghanaians, accounting for between 47 and 50% of food intake (Edwards,1995). Examples of food prepared from maize are Kenkey, Banku, Koko, Fresh corn (boiled or roasted) and maize drink (“alasa”) considered as fast food convenient for urban dwellers, much as hamburgers are enjoyed elsewhere. Infact, it is a politically sensitive crop to urban dwellers, such that the size of-a ball of Kenkey was once shown in parliament as a reflection of the state of the economy (Edwards,1995). It is a source of protein in Ghana and thus features, prominently in infant foods such as ‘Weanimix’ and ‘Vitalmix’, and also in animal nutrition (Edwards,1995). Maize ranks only after fish and legumes in terms of annual protein production (Twumasi-Afriyie *et al.*, 1992).

Maize grain is at present the main energy source in non-ruminants (Edwards, 1995). It is also an outstanding feed for livestock, high in energy, low in fibre and easily digestible. It is an important forage crop; being cut green, or dried for fodder or made into silage and over 500 important products and byproducts may be obtained from maize (Purseglove, 1992).

## **2.2. The African locust bean (*Parkia biglobosa* Jacq.)**

### **2.2.1. Taxonomy, distribution and ecology**

*Parkia biglobosa* (Jacq.) Benth was first described by Robert Brown in 1825 and he named it after Mungo Park, a Scot who had made remarkable journeys of exploration into the interior of West Africa (ICRAF, 2004). *Parkia* is a pan tropical genus comprising about 30–40 tree species which occur in Africa, Asia, and in South America (Hopkins, 1983 ; Luckow and Hopkins, 1995). *Parkia biglobosa* is a perennial deciduous tree with a height ranging from 7–20 metres and can reach 30 metres under exceptional conditions (Cobbina and Sabitti, 1992 ; Shao, 2002 ; ICRAF, 2004) (See Plate 1). It is noted to be widely distributed in Africa (Cobbina and Sabitti, 1992), and the following are its synonyms: *P. africana* R. Br; *P. clappertoniana* Keay; *P. filicoidea* var. *glauca* Baker; *P. oliveri* J .F. Macbr; *P. filicoidea* Oliver; *Mimosa biglobosa* Jacq.; *Inga biglobosa* (Jacq.) Wild.; *Inga faeculifera* Desv and *P. intermedia* Oliver (ICRAF, 2004). A number of vernacular names appear in the literature: two ball nitta tree, fern leaf, monkey cutlass tree, arbre a farine, arbre a fauve, mimosa poupre, caroubier africain, nerre,

neri, nete, nette, oul, ouli, se-ou, ulele, yif, mkunde, mnienze (Dalziel and Hutchinson, 1937; Burkill, 1995; ICRAF, 2004).

Hutchinson *et al.* (1958) recorded four indigenous species of the genus *Parkia* in West Africa and these include *P. biglobosa* (Jacq.) Benth; *P. clappertoniana* Keay; *P. bicolor* A. Chev; and *P. filicoidea* Welw. Ex. Oliv. Burkill (1995) reported that recent monographic work has reduced the number of species to two common ones: *P. biglobosa* which are known to be distributed from Senegal across the West African sub-region into Southern Sudan and are mainly savanna species and *P. bicolor*, which overlaps with dispersal from Guinea to Eastern Zaire and is mainly a forest species. *Parkia filicoidea* is a species of Central to East Africa with restricted, disjointed and rare occurrence in the highlands of Cote d'Ivoire, Ghana, Togo and Eastern Nigeria. It is probable, however, that species names are interchangeable and usages are applicable more or less, commonly to all. IAPT (1997) confirmed that *P. biglobosa* (Jacq.) R. Br. ex G. Don is the name in current use of the extant plant genera.

*Parkia biglobosa* occurs in a diversity of agroecological zones, ranging from tropical forest with high and well distributed rainfall to arid zones where mean annual rainfall may be less than 400 mm (ICRAF, 2004). Mean annual rainfall for *Parkia* trees ranges from 500–1200 mm (Le Houérou, 1986). Felker (1981) observed *Parkia* growing in areas with less than 400 mm but was dominant in

areas with rainfall of 600 – 700 mm. It thrives in Southwestern Nigeria in areas with rainfall of about 1500 mm. *Parkia* has a capacity to withstand drought conditions due to its deep tap root system and ability to restrict transpiration (Osunubi and Fasehun,1987 ; ICRAF,2004).

*Parkia biglobosa* has a wide distribution across the Sudan and Guinea savanna ecological zones (Cobbina and Sabitti,1992 ;Burkill,1995). The range extends from the Western coast of Africa in Senegal to Sudan (Shao,2002). *Parkia biglobosa* is found in nineteen African countries: Senegal, The Gambia, Ghana, Guinea Bissau, Sierra Leone, Mali, Cote d'ivoire, Burkina Faso, Togo, Benin, Niger, Nigeria, Chad, Central African Republic, Zaire, Sudan and Uganda (Burkill, 1995 ; Hall *et al.*, 1997 ; ICRAF, 2004). In Ghana *P. biglobosa* is found in appreciable numbers only in the North, and its distributions conform to common environmental factors throughout its range (Shao, 2002).



Plate 1: *Parkia biglobosa* tree in Mole National Park, Ghana (Shao, 2002).

### **2.2.2. Economic importance**

*Parkia biglobosa* has several functional uses and is very important because of its products (Burkill,1995). The most significant products are food. The food products collected from *P. biglobosa* are especially important due to the seasonality of fruit maturation and food availability (Shao,2002). All parts of the tree are useful in one-way or the other. In The Gambia, it is protected from felling by the native authority and it assumes such importance as a food-legume that native husbandry has developed special names for the various parts of the tree and

these are often without epithet e.g. “The tree” or “The seed” is understood to mean *Parkia* (Burkill,1995).

The leaves were valuable famine food in Northern Nigeria in 1972 – 74 (Burkill, 1995). In Ghana, powdered dried barks and roots when mixed with shea butter can be applied to the whole body of children suffering from convulsion (Burkill, 1995). The whole pods is edible when fresh and is eaten throughout West Africa. Even when dried, a large proportion remains edible. Thus, pods were often taken on long journeys as a staple ration (See Plate 2). In Ghana, water is added to the pulps to produce a paste called “dozim” in Dagbani. In February or March, young green pods are roasted and eaten by men. In March and April, the beginning of “hunger” season when other foods are scarce, mature pods are collected for food (Shao,2002).

The seeds are used in the preparation of dawadawa, a protein and fat rich food (Shao,2002). Dawadawa is a traditional culinary product obtained from the fermentation of African locust bean (*P. biglobosa*) by *Bacillus* spp.(Odunfa, 1986). It is considered the most important food condiment in the entire West/Central African savanna region. Dawadawa is primarily used as a condiment or flavours intensifier for soups and to impart or enhance meatiness (Beaumont, 2002). Dawadawa is the name designated by the Nigerian Hausa tribe for fermented locust beans. Similar fermentation has been characterized throughout

Africa, with local adaptation in the form of raw material selection. These regional versions are often given local names such as Kinda in Sierra Leone, lru in coastal Nigeria, Soumbara in The Gambia and Burkina Faso and Kpalugu in parts of Ghana (Odunfa,1986).

Dawadawa is rich in protein, lipids and vitamin B2 and abundant in amino acids and in the Northern region of Ghana, ten percent of all meals contain dawadawa (Campbell–Platt, 1980). In Northern Nigeria, dawadawa constituted 1.4 percent of the daily calorie intake and 5% of the total protein intake (Odunfa,1985). The young seedlings are nutritious and heavily browsed by livestock. Seeds are rich in calcium, sodium, potassium and phosphorus; they are used as a coffee substitute (ICRAF, 2004).

*Parkia biglobosa* attracts bees and is a popular tree among beekeepers. Branches are sometimes loped for firewood. Pods and roots are used as sponges and as strings for musical instruments. Mucilage from part of the fruit is used as gum or resin. Husk of pods mixed with indigo improve the luster of dye products; seeds and bark contain tannin and so the bark is used in tanning. Fresh pulp can be fermented into an alcoholic beverage. The bark and pods contain piscidic acid; the alkaloid parkine occurs in pods. The bark is also used for traditional medicine (Burkill,1995 ; ICRAF, 2004).



Plate 2 : *Parkia biglobosa* fruit bunches, the form used for the experiments

### **2.3. Insect pests of *Parkia***

*Parkia* is an important tree, intercropped with guinea corn or maize (Fagbemi, 1989). Since it is grown in the same field with food crops; it may be an important alternate host of some insect pests which constitute a source of infestation to nearby crops. Setamou *et al.*(2000a) recorded several generations of corn ear borer, *M. nigrivenella* on pods of *P. biglobosa*, which constitute an important source of infestation to nearby maize fields.

A weevil and pyralid moth were observed on the pods; the moth eats both pulp and seed. Four families of Lepidoptera eat leaves of *P. biglobosa* and timbers are readily attacked by insects such as termites and wood borers (ICRAF, 2004). Hall and Walker (1991) reported that storage structures, made from *Parkia clappertoniana* and shea butter woods, are susceptible to insect attacks.

#### **2.4. Taxonomy of *Sitophilus zeamais***

The maize weevil, *Sitophilus zeamais* Motschulsky is a member of a triumvirate of species in the family Curculionidae, Subfamily Caladrinae, genus *Sitophilus* which is stored grain pest. Other species are the rice weevil, *S. oryzae* (L.) and the granary weevil, *S. granarius* (L.). It was first described by Linnaeus in 1763 as *Curculio oryza*, the first named species of the group which was later revised by De Clairville and Scheltenburg in 1798 as *Calandra oryzae*; it uses the commonest generic synonym for *Sitophilus*. Many workers subsequently recognized that two distinct forms of the species existed and were described as the 'large' and 'small' forms. In 1855, Motschulsky recognized the large form as a distinct species, which he named *Sitophilus zeamais*. Unfortunately, few workers recognized this revision and the name *C. oryzae* continued to be applied to all insects in this complex. Takahashi in 1928 and 1931 complicated matters by raising the small form to specific status as *C. sasakii*. This confused situation continued until 1959, when Floyd and Newsom (1959) revised the complex; this was followed by a further

revision by Kuschel (1961). In these revisions it was shown that Linnaeus originally described the smaller species and that Motschulsky's description of the larger species was valid. Both species were therefore placed in the genus *Sitophilus* with the specific names proposed by Linnaeus and Motschulsky.

Unfortunately, the difference in size between *S. oryzae* and *S. zeamais* is not consistent, so it is not possible to be sure that references to the large and small forms of *C. oryzae* refer to *S. zeamais* and *S. oryzae*, respectively. Therefore the only true and unconfused synonym of *S. oryzae* is *C. sasakii*; in pre-1960's literature, *C. oryzae* 'small' and 'large' forms could refer to either *S. zeamais* or *S. oryzae*, and it is also possible that some references to '*S. oryzae*' in the 1960's and early 1970's literature actually relate to *S. zeamais* misidentified by use of old keys. The genus *Sitophilus* and its species may be identified using the keys of Gorham (1987) or Haines (1991).

*Sitophilus oryzae* and *S. zeamais* are almost indistinguishable from each other externally (Haines,1991). Body sizes of adult range from 2.5 to 4mm and the thorax is large and conspicuous (Hill,1983). The body colour varies from light brown to black. Both species usually have four pale reddish-brown or orange-brown oval markings on the elytra. Both have the characteristic rostrum and elbowed antennae of the family Curculionidae which are carried in an extended position when the insect is walking. Separation of *S. oryzae* and *S. zeamais*

requires examination of the genitalia. The aedeagus of *S. zeamais* has two parallel grooves on its dorsal surface; these are absent in *S. oryzae* making this structure in the latter smooth and convex (Halstead,1963 ;Proctor,1971). In female *S. zeamais*, the prongs of the Y – shaped sclerite are pointed at the ends and the gap between is wider than the combined width. However in *S. oryzae*, the prongs are rounded and the gap between them is narrower than their width (Vowotor,1992). Arrangements made by pronotal pits on the prothorax can also be used to differentiate the two species. Halstead (1963) and Fisher (1987) reported that the rostrum of the male *S. zeamais* and *S. oryzae* are distinctly shorter and wider than that of the female. Furthermore, the rostrum of the female in both species are comparatively longer and narrower than those of the males; the rostrum of the female is smooth and shining while that of the male is rough. It is sometimes difficult to distinguish between *S. zeamais* and *S. oryzae* based on morphological characteristics (Lale and Ofuya, 2001 ; Adedire, 2001). However, in *S. zeamais*, the adult weevil is larger and the patches on the elytra are more easily discernible than in *S. oryzae* (Appert, 1987). It is a better flier and prefers larger grain than the rice weevil. The granary weevil, *S. granarius* on the other hand is seldom found in the hot tropical regions except on grains imported from the temperate countries (Appert,1987). It is easily distinguishable from the other two species by the absence of dark patches on the elytra and its inability to fly. Nardon and Nardon (2002) reported that *S. zeamais* and *S. oryzae* can be distinguished by the following new characters:(1) In the larvae, there exists a small difference exists in

mandible structure with the apical zone more depressed in *S. oryzae* than in *S. zeamais*. (2) In adults, four new distinctive features which occur are: (i) The structure of the metathoracic episternum with two rows of punctures in *S. oryzae* and three in *S. zeamais*. (ii) The frontal groove much more depressed in *S. zeamais* than in *S. oryzae*. (iii) The complex setae bordering the frontal groove bigger in *S. oryzae* than in *S. zeamais* and (iv) The presence of a little structure called "rosette", at the base of the rostrum, easy to see in *S. zeamais* but less visible in *S. oryzae*. Both species can also be separated from *S. granarius* by the presence of metathoracic flight wings, and oval-shaped punctures on the prothorax of the former (Haines, 1991).

## 2.5. Biology of *S. zeamais*

*Sitophilus zeamais* undergoes holometabolous metamorphosis; they have four life stages- egg, larva, pupa and the adult. Total developmental periods from egg to adult range from 30-35 days under optimal conditions to over 110 days at sub-optimal conditions of temperature and relative humidity (Richards, 1947 ; Haines, 1991). The actual length of the life cycle also depends upon the type and quality of grain being infested; for example, in different varieties of maize, mean development periods of *S. zeamais* at 27°C and 70% r.h. have been shown to vary from 31 to 37 days (Birch, 1944 ; Howe, 1952 ; Longstaff , 1981 ; Haines, 1991). *Sitophilus zeamais* is a multivoltine insect pest, producing up to 7 generations in

one year (Hill, 1983 ; NRI, 1996). The longevity of the adult weevil is from a few months to one year (Longstaff, 1981 ; Lale, 2002).

### **2.5.1. Eggs**

Eggs are laid throughout most of the female adult life, although 50% may be laid in the first 4-5 weeks; each female may lay about 300 to 400 eggs in its lifespan (Adedire, 2001). Each female lays 2 to 3 eggs per day during her life (NRI, 1996). The eggs are laid individually in small cavities chewed into cereal grains by the female; each cavity is sealed, thus protecting the egg by a waxy secretion (usually referred to as an 'egg-plug') produced by the female. The incubation period of the egg is about 6 days at 25°C (Howe, 1952). Eggs are laid at temperatures between 15 and 35°C (with an optimum around 25°C) and at grain moisture content of over 10%. However, rates of oviposition are very low below 20°C or above 32°C, and below about 12% moisture content (Birch, 1944).

### **2.5.2. Larvae**

Eggs hatch after about 8 days into legless, 4 mm long larvae (NRI, 1996). The larvae are plump creamy white in appearance and apodous, hence they are immobile; the larvae commonly called grubs which feed exclusively on the grain (Adedire, 2001). The larval stage is the most destructive stage of the weevil and accounts for most of the damage to the grains. The larva chews through the grain kernel leaving a characteristic tunnel and develops through 4 instars (Sharifi and Mills, 1971a ; Shade *et al.*, 1990 ; Vowotor, 1992 ; NRI, 1996 ; Adedire, 2001).

The chewing activity of the larva is responsible for loss in quality and quantity of the stored crops (Urrelo *et al.*,1990). At the next larval moult; the larva increases in size, thereby widening the tunnel. The duration of the larval stage is about 21 days at 25° to 27°C and 70% r.h.(Sharifi and Mills,1971b). The first and fourth instars have been found to be longer than the second and third instars (Urrelo and Wright,1989).

### **2.5.3. Pupae**

The fourth instar larva lives within the chamber and moults into a prepupa. The duration of this prepupal stage is about one day (Sharifi and Mills,1971b ; Baker and Mabie,1973), after which it moults into a pupa for about 6 days (Vowotor, 1992). After emerging from the puparium, the newly developed adult remains inside the kernel for several days before emerging. The extent of this period varies with temperature among other factors (Vowotor, 1992). Duration of pupal period lasts from 5 to 16 days (NRI, 1996).

### **2.5.4. Adults**

The adults emerge after a further 5-16 days and will live for about 9 month. The adult emerges through a circular hole which it has cut out of the grains (NRI, 1996). The holes are characteristic of this insect pest. Adults reach a length of 3 - 3.5mm long (average 3 mm); dark brown, nearly black with four clearly defined reddish spots on the elytra; 8-segmented antennae; prothorax with round or

irregular punctures; hindwings present (NRI,1996). *Sitophilus zeamais* has a greater ability and tendency to fly (Giles,1969). Where grain is stored on small farms, *S. zeamais* is thus more likely than *S. oryzae* to fly to the ripening crop in the field and establish an infestation in the grain before harvest.

#### **2.5.5. Reproduction**

In *S. zeamais*, reproduction occurs with mating. Mating may take place many times and sperms are stored for many days (Vowotor,1992). Virgin males are often found on the grain surface. Surtees (1964) reported that virgin females spend more time on the surface of a grain mass, as compared to mated female which spend most of their time feeding and ovipositing. Ayertey (1981) reported that virgin males were more active than virgin females. Walgenbach and Burkholder (1987) further explained that virgin females began copulation sooner and are more likely to mate than previously mated females. Mated males were reported to be more successful at mating than virgins. Copulation lasts for an average of 4.8 hours and does not usually occur before the age of 3 days (Vowotor,1992). The duration of copulation is neither affected by the age of mating status of the female nor by the period of time since first copulation. Aggregation pheromones are reportedly produced by males before mating. Mated females are significantly less responsive to it than virgins. Mated males are also less responsive although less so than mated females (Walgenbach and Burkholder, 1986). Aggregation pheromone systems are highly tied to food

resources, as studies indicate that feeding is required by males to produce pheromone and optimum response by females and males is achieved when the aggregation pheromone is released together with food odours (Phillips, 1997).

## 2.6. Ecology and distribution

*Sitophilus zeamais* and *S. oryzae* are found in all warm and tropical parts of the world but *S. oryzae* may also be found in temperate regions of the world (Hill, 1983 ; Appert, 1987 ; Adedire, 2001). The maize weevil is one of the most serious cosmopolitan pests of stored cereal grain, especially of maize in tropical and sub-tropical regions (Throne,1994). Food preference of the two species are variable; *S. zeamais* is a serious primary pest of maize while *S. oryzae* is a principal pest of rice in the tropics and other warm regions of the world (TDRI,1984 ; Adedire,2001). *Sitophilus granarius* on the other hand is seldom found in the hot tropical regions except in grains imported from the temperate countries (Appert, 1987).

## 2.7. Feeding and breeding substrates

*Sitophilus zeamais* is a serious primary pest of maize while *S. oryzae* is a principal pest of rice in the tropics and other warm regions of the world (Haines, 1991 ; Lale and Ofuya,2001). *Sitophilus zeamais* is secondarily found attacking other crops such as rice, sorghum, yam products, groundnut, cowpea, millet, dried cassava, cassava flour, cocoyam, beniseed, triticale, processed cereal products such as pasta

(Haines, 1991 ; Nwanna,1993 ; NRI,1996). *Sitophilus oryzae* is also a secondary pest of all these stored produce except rice which happens to be its major host (Lale and Ofuya,2001). *Sitophilus oryzae* strains have been found which can develop on legumes, peas (Coombs *et al.*,1977 ; Haines,1991). *Sitophilus granarius* is known to attack smaller cereal grains such as wheat, millet, sorghum, barley etc, but they are occasionally found on larger grains (Lale and Ofuya, 2001). Delobel and Grenier (1993) reported the development of *S. zeamais*, *S. oryzae* and *S. linearis* on non-cereal foods and it shows the adaptability of cereal weevils to different seeds and high performance on chestnuts and acorns. William and Floyd (1971) also reported that *S. zeamais* were found on several wild host plants such as sunflowers.

## **2.8. Economic importance**

*Sitophilus zeamais* is an important pest of maize but it was also associated with other cereals and processed food. Adult and larvae feed on undamaged grains and reduce them into powdery form. Infestation may commence from the field just before harvest and continues to reproduce and destroy the grains in the store. The larvae develop and pupate within grains. The developmental activities of the weevil often lead to severe powdering and tainting of the grains with excrement. The infested grains are often rendered susceptible to caking and mould infection thereby reducing their market value (NRI,1996 ; Adedire, 2001 ; Lale and Ofuya,

2001). In stored maize, heavy infestation of this pest may cause weight losses of as much as 30-40%, although losses are commonly 4-5% (Lale and Ofuya, 2001).

## **2.9. Management**

There are a number of control strategies employed to control maize weevil both in the field and in storage. These may be grouped into four broad methods: cultural, physical, chemical, biological. The three principal approaches to the protection of stored grain: physical, biological and chemical are collectively known as integrated pest management (Proctor, 1994).

### **2.9.1. Cultural control**

Cultural control methods include the burning of cobs and sheath from which the maize was shelled, storage of the crop in improved ventilated cribs, early harvesting to eliminate or reduce field infestation (FAO,1985). Cleaning of bins or granaries, avoidance of mixing infested grains with healthy ones, burning crop residues after-harvest, sealing cracks and crevices in muddy structures and any other practices that ensure that the crop is stored in a clean and uncontaminated environment (Proctor,1994). Sanitation is a simple practice that can save the product from losses due to infestation. Good sanitation involves the removal of old grain and dust in and around the grain bin, removal of old grain from corners, floors, and walls and grain that may have spilled on the exterior of the bin, removal of any unnecessary objects from the store, cleanliness of the store through

sweeping, removal of left over and prompt burning of the trash is essential before receiving in a new lot. Sanitation in stores is a key factor for preserving products in good condition (Suss and Locatelli, 1993 ; Vinuela *et al.*, 1993 ; Rotundo *et al.*, 1995).

### **2.9.2. Physical control**

The physical methods of controlling pests in storage includes the following:

Physical disturbance of grain, by turning it from one elevator bin to another, can reduce live grain weevil infestation to a considerable extent due to physical stress and damage due to handling and processing of the grain (Joffe,1963). Hygiene and physical removal of infestation nuclei, including commodity residues, secondary or unproductive primary hosts for field pests, cleaning, hand-picking, sun drying to drive away insects; cleaning should involve brushing and washing and disposal of all residues containing or supporting live insects (Hall,1970 ; Proctor,1994). Physical control also include all methods which reduce the moisture content of the crop for safe storage (Dobie,1984). Infestation of stored maize can be reduced by storing it as unhusked cobs; a long tight husk cover on maize cobs will physically prevent infestation in some instances (NRI,1996). Inclusion of silica-containing dusts and ash with stored grain has been found to control effectively storage insects (Proctor, 1994). They may be used at rates above 30 percent of the weight of the grain. Dusts made of silica aerogels, various clays, diatomaceous earth, activated carbon, pyrophyllite and a number of other silicates kill insects by absorbing or abrading

the waxy layer from their cuticle, causing desiccation and death (Proctor,1994). Ajayi *et al.*(1987) reported the control of *S. oryzae* with wood ash and refined palm oil. Seed treatment with wood ash or dung ash at 1.5% was effective in controlling *S. oryzae* and ash from the plant of *Tamarindus indica* was shown to protect stored grains for 7 weeks (NRI,1996). Hall (1970) reported on an experiment in Kenya using a diatomite dust of local origin, this mineral dust, when applied to stored maize in bags was believed to scratch the waterproofing layer of the wax surfaces of insect cuticle and led to the death of the insects. Diatomaceous earth preparations and mixtures with silica aerogel showed some effects on the reproduction rate of *S. granarius* (Flachsbarth *et al.*, 2000). The powders derived from various diatomaceous fossil deposits were effective as an insecticide against *Rhyzopertha dominica*, *Tribolium. castaneum*, and *S. oryzae* (Baldassari *et al.*, 2002). Experiments showed that washed ash from burnt cow dung worked faster than unwashed ash; on average washing shortened the mortality period by 30% and the knock-down period by 45% and was effective against *S. granarius*, *Cryptolestes ferrugineus*, *T. castaneum*, and larvae of *Tenebrio molitor* and *Calliphora vomitoria* (Hakbijl, 2002). A lower dose of 3g/kg diatomaceous earth (DE) as a top-dressing for prophylactic control reduced the numbers of *Oryzaephilus surinamensis* and *S. granarius* by greater than 90%. The use of DEs as part of an IPM strategy was emphasized and lower doses could be commercially effective (Cook *et al.*, 2002). Mortality of adult *S. zeamais*, in

wheat treated with diatomaceous earth was always greater than controls, and ranged from 56 to 90% at 22°C and was >90% at 32°C (Arthur and Throne, 2003).

### **2.9.3. Chemical control**

Use of fumigants and insecticidal dusts can be employed for chemical control of the maize weevils. Chemical control methods have the advantage of effectiveness, simplicity, versatility, low cost and immediate availability (Appert, 1987 ; Proctor, 1994). Dusting and fumigation of grains are the most commonly used chemical methods among small-scale farmers (Rai *et al.*, 1987). The most commonly used insecticide dusts belong to two main groups of chemicals: organophosphorus compounds (such as chlorpyrifos-methyl, fenitrothion, etrimfos, malathion, methacrifos and pirimiphos-methyl) and pyrethroids (such as cyfluthrin, deltamethrin, fenvalerate and permethrin). Fumigation is a widely used method all over the world on small-as well as large scale storage. The method can be applied at the farm level in gas-tight granaries or silos, under gas-tight sheets carefully covering the product or at large scale storage as in large warehouses. Fumigants are commercially available in a solid, liquid or gaseous state. There are various gases which can be used and these are: Methyl bromide (a possible ozone depleter, scheduled for deregistration in 2005), nitrogen, phosphine and carbon dioxide (Krall, 1984 ; Auger *et al.*, 2002).

Moreno *et al.*(2002) reported on the control of *S. oryzae* and *O. surinamensis* using carbon dioxide under increased pressure (1, 25, 60 and 100 bar) at temperatures of 20, 40 and 60°C, and durations of 5, 30 and 60 minutes, where stored pests were effectively controlled at 60°C, 1 bar and 60 minutes, as well as at 25 bar and 5 minutes. At 20 and 40°C, 25 bar and 30 minutes, mortality was 100%. Studies have also shown that organophosphorus insecticides, such as pirimiphos-methyl, tetrachlorvinphos and malathion effectively control grain weevils, keeping grains protected for 8 months (McFarlane, 1975 ; Golob *et al.*, 1985). Pyrethroids like permethrin, deltamethrin or fenvalerate plus fenitrothion in powder formulation of 0.5 % w/w, applied at 2.5-3.0 ppm on shelled maize or cobs, have been shown to give protection for 10 months or more and do not present any residual problems for human consumption (Golob *et al.*, 1985 ; Makundi,1986). It was therefore recommended that on mixed infestations by *P. truncatus* and *Sitophilus* spp. a combination of organophosphate and pyrethroids, such as pirimiphos-methyl and deltamethrin, will give an excellent control of both pests. Aburto and Garza (1986) reported the control of *Sitophilus* spp. in stored grain with pirimiphos-methyl and trimethacarb; trimethacarb gave good control and had no residual effect after one month.

#### 2.9.4. Novel Approaches

The novel methods for possible application in stored-grain pest control include control by the use of predators, parasites, insect diseases and sterile males, the use of pheromones for pest monitoring, mating disruption or enhanced mass trapping, and the use of insect growth regulators (IGRs)

Biological control may provide a useful and safe alternative for the control of crop pests (Proctor, 1994). Both *S. zeamais* and *S. oryzae* are commonly parasitized by pteromalids (and occasionally other Hymenoptera). Common pteromalid parasites include *Anisopteromalus calandrae*, *Lariophagus distinguendus* and *Theocolax elegans* (Dobie, 1984). The parasitoid, a predator or a pathogen manipulate the reproductive processes, behaviour, feeding and other biotic aspects of the pest. A parasitoid resides and feeds on the host pest itself which eventually dies (Proctor, 1994). Suppression of *S. zeamais* populations in drums of corn by single and multiple releases of the parasitoid *A. calandrae* reached over 90 % (Wen and Brower, 1994). The use of insect pathogens such as *Bacillus thuringiensis* is considered as an alternative to synthetic insecticides; *B. thuringiensis* subsp. Morrison and *B. thuringiensis* subsp. Tenebrionis were effective for the protection of stored grains from pest infestation. (Abdel-Razek, 2002).

Entomopathogenic fungi (e.g. *Beauveria* spp.) used as mycopesticides may also provide an environmentally safe and cheap alternative for controlling storage

insects: *Metarhizium anisopliae* and *Beauveria bassiana* were virulent to *S. zeamais* and 92-100% mortality was recorded (Kassa *et al.*,2002).

The use of pheromones provide an alternative mechanism, being non – neurotoxic, and is one of the most promising techniques aimed at the control of stored product insects that may lead to a drastic reduction of chemical treatments against crop pests (Trematerra, 1997). Pheromone traps can be used to monitor the dynamics and occurrence of different stored product pests, such as male aggregation pheromones known as “Sitophilure” for monitoring pest population and lures to attract maize weevils (Hodges *et al.*, 1998 ; Ronaldo and Valeria,1999). Allium’s allelochemicals (thiosulfinates) has repellent and antifeedant activity (Auger *et al.*, 2002).

Insect growth regulators (IGRs). These compounds have been found highly effective against various stored-product and other insect pests, including pest strains that are resistant to organic insecticides. Generally IGRs have very low toxicity to mammals and other non-target organisms and, rapidly degrade in the environment (Kostyukovsky *et al.*,2000). These characteristics make IGRs potential alternatives to conventional insect pests control measures. According to their modes of action, IGRs are divided into three main groups: juvenoid, which mainly affect larval metamorphosis by mimicking juvenile hormone; ecdysteroid, which affect moulting; and chitin synthesis inhibitors (CSIs) which interfere with

cuticle formation (Post *et al.*,1974 ; Bengston1987 ; Gwinner *et al.*,1990), though the mode of action remains elusive (Ishaaya and Horowitz,1998; Oberlander and Silhacek,1998). Among the diverse in vivo actions of CSIs on the life cycle of insect pests of various orders are ovicidal and larvicidal effects (Ascher *et al.*, 1987). Impairment of cuticle secretion in affected embryos may be the cause of the hatchability reduction that results from treatment with CSIs (Elek, 1998). The larvicidal effects of CSIs are most likely achieved through interference with the formation of a new cuticle (Oberlander and Silhacek, 1998 ; Kostyukovsky and Trostanetsky,2005). Chitin synthesis inhibitors (teflubenzuron, benzamide, chlorfluazuron, and diflubenzuron) decreased the fecundity of *S. granarius* and *Acanthoscelides obtectus* while juvenile hormone analogue (fenoxycarb) and chlorpyrifos-methyl could give good protection for at least 12 months against *T. castaneum*, *O. surinamensis*, *R. dominica* and *S. granarius* (Nawrot *et al.*, 1987 ; Edwards *et al.*, 1987). Fenoxycarb controlled populations of *O. surinamensis*, *R. dominica* and *T. castaneum* for 2 years, but was not completely effective at controlling populations of *S. granarius* (Mkhize,1988 ; Edwards *et al.*,1991). Silica aerogels used alone and in combination with IGRs were effective against *S. oryzae* and *S. zeamais* adults and afforded 91-98% control of the weevils (Ammar, 1988;Casaco *et al.*, 2002 ; Conceicao *et al.*, 2002). Diflubenzuron and methoprene were effective in protecting stored sorghum from *S. oryzae* and *R. dominica* under commercial storage conditions. (Daglish and Wallbank, 2005)

Botanical insect deterrents or seed protectants may be applied to some products with varied degrees of success. Plant products such as neem powder, neem extracts, leaves of hoary basil (*Ocimum* spp.), mint (*Mentha* spp.) or black pepper (*Piper* spp.), Chinaberry tree (*Melia azedarach*) extracts, Alligator pepper (*Aframomum melegueta*) seed powder and oil extract, seed extracts of Castor bean (*Ricinus communis*) showed some positive results in limiting insect infestation. (Kossou, 1989 ; Haubruge *et al.*, 1989; Cobbinah and Appiah-Kwarteng , 1989). Leaves and stems of maize and sorghum, powder from dry ground leaves of Mexican tea (*Chenopodium ambrosioides*), leaves of post-harvest grain maize, sorghum, seed powder and oil of black pepper, *Piper nigrum*, *P. guineense*, *P. umbellatum* and *Capsicum frutescens* showed good results in reducing damage by certain pests and also caused high adult mortality (Ojo, 1991 ; Lale, 1992 ; Risha, 1993 ; Ishrat *et al.*, 1994 ; Jembere *et al.*, 1995). Other extracted oils, such as palm kernel oil, copra seed oil, citrus peel oil, maize oil, soyabean oil, groundnut oil, have been recognized as toxicants or growth inhibitors (Mahgoub and Ahmed, 1996 ; Okonkwo and Okoye, 1996 ; Adedire, 2001 ; Wongtong *et al.*, 2001 ; Tapondjou *et al.*, 2002 ; Bekele, 2002 ; Obeng-Ofori and Amiteye, 2005). Oils of groundnut, soyabean, castor, coconut, sesame, *Lippia adoensis* oil and olive have been reported to effectively control *S. zeamais* infestation and caused 100% mortality of adult *S. oryzae* (Ivbijaro, 1984 ; Salas, 1985 ; Odeyemi, 1993). Oils from *Xylopia aethiopica* Dunal, *Ocimum gratissimum*, *P. nigrum* killed 97%, 74%, 96% of *S. zeamais* (Ngamo *et al.*, 2001).

Plant extracts of the following: *Azadirachta indica*, *Chromolaena odorata*, *Cissampelos owariensis*, *Datura metel*, *D. stramonium*, *Ricinus communis*, *Erythrophleum suaveolens*, *Grewia carpinifolia*, *Sida acuta*, *Solanum nigra*, *Strophantus hispidus* and pulverized seeds of *Uvaria afzelli*, *P. umbellatum*, *Eugenia aromatica* and the bark of *Erythrophleum guineense* were highly toxic to *S. zeamais*, *S. oryzae*, *A. obtectus* and *P. truncatus* (Niber *et al.*, 1992 ; Ladije *et al.*, 1998). Leaves from *Eucalyptus globulus*, *Schinese molle*, *Datura stramonium*, *Phytolacca dodecandra*, and *Lycopersicum esculentum* cause high adult weevil mortality for *S. zeamais* (Firdissa and Abraham, 1999).

Eugenol, isoeugenol and methyleugenol were effective against *S. granarius*, *S. zeamais*, *T. castaneum* and *P. truncatus* with overall repellency in the range of 80-100%, and development of eggs and immature stages inside grain kernels was completely inhibited (Obeng-ofori and Reichmuth, 1997 ; Huan *et al.*, 2002).

## CHAPTER THREE

### 3.0. GENERAL METHODOLOGY

#### 3.1. Study area

The studies were carried out in the Entomology Laboratory and in the Screen house at Sinna Garden both at the Crop Science Department, University of Ghana, Legon from July 2004 to June 2005.

#### 3.2. Test plants

*Parkia* seeds, pods and pulps (about 10kg) and maize grains (about 10kg) were obtained from markets in Northern Ghana and Southern Ghana, respectively, and kept under cold storage at a temperature of 10 °C.

#### 3.3. Culturing of *Sitophilus zeamais*

*Sitophilus zeamais* adults (See Plate 3) were obtained from a stock culture maintained on maize at the Ghana Atomic Energy Commission and cultured in the Entomology laboratory of the Crop Science Department. This provided a source of supply of insects for the studies. Sub-samples of maize grains (about 2500g) were withdrawn from the lot purchased from market and frozen in a deep freezer at about 1 °C for two weeks to disinfest the grains (TDRI, 1984 ; Valerie *et al.*, 1989 ; Hodges and Dobsona, 1998). The maize grains were then sterilized in a Gallenkamp Oven at 60 °C for 3 hours, to kill off insects that may have survived the freezing temperatures. 1000 ml glass jars were also sterilized at 60 °C for 3 hours

(Allotey and Azalekor, 2000). After cooling, about 500g of the maize grains were put into each glass jar. One hundred, 7-14 day old unsexed adults *S. zeamais* were introduced into each glass jar with an aspirator and five of such cultures in jars were prepared. Each glass jar was covered with a lid which is cut in the middle but sealed with a mesh (4cm in diameter) to facilitate ventilation of the culture but keeps in the desired insects while it kept out mites and other unwanted insects. All the cultures in glass jars were held in trays with supports immersed in engine oil to prevent insects from crawling into them. After 7 days of oviposition, the adult insects were sieved out with (6–mesh/in) (John Laing International Ltd, U.K.). This was repeated daily for three consecutive days to ensure thorough removal of all adult insects. The cultures were kept for four weeks until adult emergence. Adults (7-14-day old) that emerged from these cultures were used to set up the experimental cultures. Re-culturing of the insects was carried out at regular intervals to ensure availability of experimental insects (See Plate 4).



Plate 3: *S. zeamais* adult (mag. x 100)



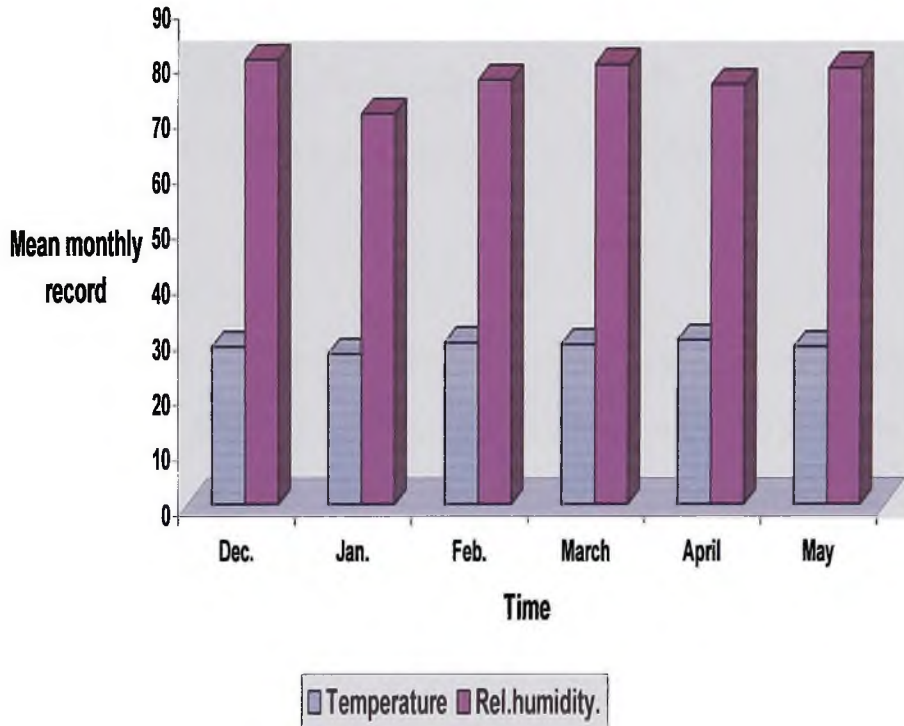
Plate 4: *S. zeamais* cultures in the laboratory

### 3.4. Experimental Design and Set Up

The experimental design used for both controlled and ambient conditions was completely randomized design (CRD). Four treatments: *Parkia* seeds, *Parkia* pods, *Parkia* pulp and maize variety Volta local which were replicated four times were randomly selected and held in trays with supports immersed in industrial oil under controlled conditions in the laboratory at 25°C, 70 ±5% r.h. Similar four treatments were also replicated four times and maintained in wooden cages under ambient conditions at the Screen house.

The experiments were conducted in an environmental chamber (model Rumed-Rubarth Apparate GmbH. Germany) at 25°C, 70 ±5% r.h. Relative humidity was maintained in the chamber with a saturated sodium chloride salt solution (Solomon, 1951). This was held in a vessel which was placed below the three shelves in the chamber on which the experimental glass jars were arranged. Temperature and r.h. in the chamber were monitored with a tiny tag data logger (Gemini Data Loggers Company, U.K.). Similar records were taken of the ambient temperature and relative humidity conditions using a thermohygrograph (See Figure 1).

**Figure 1 : Mean monthly temperature and relative humidity record from December 2004 - May 2005 obtained at Sinna Garden.**



The *Parkia* and maize substrates (experimental treatments) that were used for the experiments were set up as follows: one hundred grammes of each treatment was put into 1000 ml glass jars, and one hundred, 7-14 day old unsexed adult *S. zeamais* were introduced into each glass jar with an aspirator. Each glass jar was covered with a metal lid which is cut in the middle but sealed with a mesh (4cm in

diameter) to facilitate ventilation into the culture. Four replicates of each treatment were set up and held in trays with supports immersed in industrial oil to prevent insects from crawling into them; all trays were put into an environmental chamber (25°C, 70±5% r.h.) in the laboratory (See Plate 5). Another set of treatments was prepared similar to the previous set up and maintained in wooden cages (each cage measuring 61cm x 45cm x 41cm) under ambient conditions. The cages were mounted on shallow trays with oil to prevent insects from crawling into them (See Plate 6).

Preference test that were also conducted under controlled and ambient conditions and were set up as follows: ten grammes of four treatments (*Parkia* seeds, *Parkia* pods, *Parkia* pulp and maize variety Volta local) (See Plate 7), replicated four times, were placed on a filter paper inside Petri dishes (9cm diameter). The Petri dishes were randomly arranged in a circular form in a plastic tray (104cm x 7cm x 5cm). The trays were covered with muslin cloth. Four replicates of such trays were set up. Forty, 7-14 day old unsexed adults *S. zeamais* were introduced in the centre of the trays. The set up was observed at 24 hour intervals for a total of 72 hours



Plate 5: Experimental set-up in an environmental chamber in the laboratory.



Plate 6: Experimental set-up under ambient environmental conditions in the Screen house.

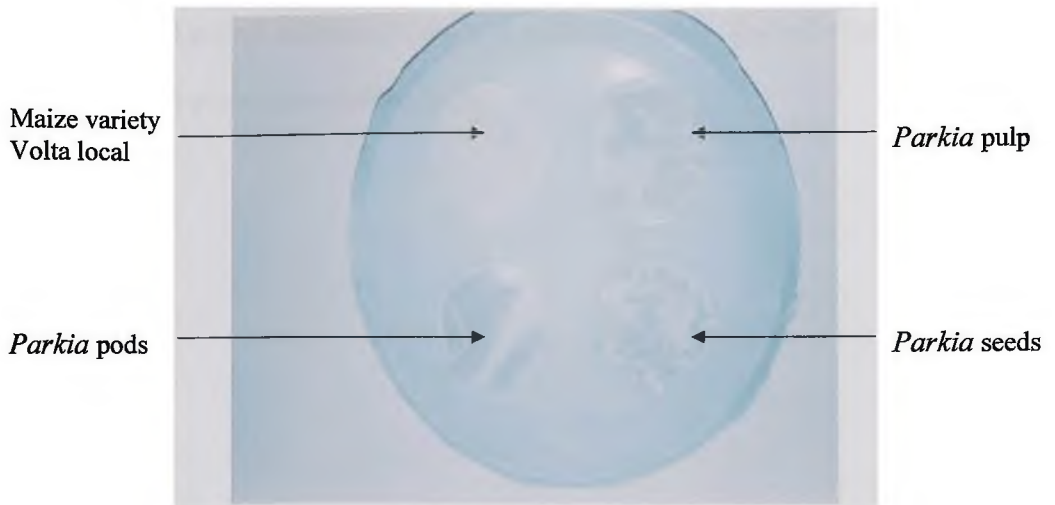


Plate 7: Tray used for the preference test, showing different *Parkia* substrates (pods, pulp and seeds) and maize.

### 3.5. Statistical analysis

Data generated from the study were analysed using Genstat Software Version 5 Release 3.2 (Lawes Agricultural Trust, 1995). Data collected on relative preference tests were transformed using square root of  $(x + 1)$ , and data on survival tests were transformed using arcsine of  $\sin^{-1}(\sqrt{x+1})$  to meet analysis of variance assumptions of normality and homogeneity of variances and subjected to analysis of variance at 95% level of significance. Means were separated using least significant difference (LSD). Graphs were drawn using Microsoft Excel and tables were used to summarize the results. As no adult weevils emerged from *Parkia* substrates, data on developmental period and mean weight of adults as well as data on oviposition were not included in the statistical analysis.

on developmental period and mean weight of adults as well as data on oviposition were not included in the statistical analysis.

## CHAPTER FOUR

### 4.0. DESCRIPTION OF EXPERIMENTS

#### 4.1. Survival of *S. zeamais* on *Parkia* and maize substrates.

##### 4.1.1. Introduction

The establishment of an insect on a host is not determined only by its ability to survive and grow on this host but also by its ability to breed on the host (Krishna and Mishra, 1985). A significant increase in the numbers of an insect on a specific food is an indication of the suitability of such product as a host for the insect. Insects are therefore known to cause considerable damage to products that are suitable to them as food (Williams, 1999). Some plant species are best for survival, others are suited for egg production (Costa *et al.*, 1991). In this study, survival tests were also conducted to determine the survival of *S. zeamais* on *Parkia* and maize substrates.

##### 4.1.2. Materials and Methods

Survival tests were conducted both at the Entomology Laboratory and in the Screen house at Sinna garden, Department of Crop Science. Before infestation, the moisture content of the *Parkia* and maize substrates were determined using a Digital Grain master (Protimeter PLC., England). The moisture content of the substrates under both set of conditions were: *Parkia* seeds (18.00%), *Parkia* pulp (16.10%), *Parkia* pods (19.70%) and maize variety Volta local (13.00%). One hundred grammes of each treatment (*Parkia* seeds, *Parkia* pulp, *Parkia* pods and

maize variety Volta local) were put into each of four glass jars, which were replicated four times and one hundred, 7–14 day old unsexed adults *S. zeamais* were introduced into each glass jar to oviposit for 7 days. The experimental treatments were randomly arranged in a completely randomized design and maintained in an environmental chamber in the laboratory (See Plate 8). Live insects were counted weekly and put back into the jars while dead insects were removed, live insects were counted for five weeks. Another set of treatments similar to the previous experimental set up were prepared and maintained in wooden cages under ambient conditions (See Plate 9).



Plate 8: Experimental set up for the survival tests in an environmental chamber in the laboratory.



Plate 9: Experimental set up for the survival tests under ambient conditions in the Screen house.

#### 4.1.3. Data collection

The numbers of both dead as well as live insects were counted weekly. An insect was considered dead if it did not respond to probes with a pin; dead insects were sieved out with an Impact Test Sieve with mesh size of 710 microns and the live insects were put back. The experiment was terminated when all adults on *Parkia* substrates had died. The experiments were repeated twice.

#### 4.1.4. Data analysis

Data collected on survival tests were converted to percentage and then transformed using arcsine of  $\sin^{-1}(\sqrt{x+1})$  and subjected to analysis of variance. The mean values were separated using LSD.

#### 4.1.5. Results.

##### 4.1.5.1. Survival of *S. zeamais* on *Parkia* and maize substrates under controlled environments.

There were significant differences ( $P < 0.05$ ) between the substrates in relation to percentage survival in the controlled environment (Table 1). The percentage survival of *S. zeamais* decreased over time on *Parkia* substrates while the survival stabilized with time on maize variety Volta local. The percentage survival recorded on maize variety Volta local in week 1 was not significantly different ( $P > 0.05$ ) from the survival recorded on *Parkia* pods. It was during week 2 that differences in the rate of survival became quite clear with highest percentage survival of the weevils was on maize ( $94.0 \pm 1.35$ ) and the lowest percentage survival was on *Parkia* seeds ( $16.2 \pm 9.3$ ) (Table 1).

**Table 1: Mean survival of *S. zeamais* on *Parkia* and maize substrates under controlled conditions from January- February, 2005.**

Substrates	Percentage survival $\pm$ S.E*				
	Week 1	Week 2	Week 3	Week 4	Week 5
Maize	$95.5 \pm 0.65^a$	$94.0 \pm 1.35^a$	$93.0 \pm 1.35^a$	$92.2 \pm 1.44^a$	$92.2 \pm 1.44^a$
<i>P. Pulp</i>	$71.2 \pm 3.54^b$	$31.2 \pm 7.3^c$	$12.2 \pm 4.19^b$	$3.7 \pm 3.12^b$	$2.7 \pm 2.43^b$
<i>P. Pods</i>	$86.0 \pm 2.3^a$	$38.0 \pm 6.49^b$	$17.7 \pm 9.06^b$	$9.7 \pm 8.47^b$	$0.2 \pm 0.25^b$
<i>P. Seeds</i>	$54.5 \pm 6.74^c$	$16.2 \pm 9.3^d$	$2.2 \pm 2.25^b$	$1.0 \pm 1.00^b$	$0.2 \pm 0.25^b$

Different *Parkia* substrates designated as *P. Pulp*, *P. Pods* and *P. Seeds*

\* Values are means of four replicates  $\pm$  standard error.

Means followed by same letter(s) in a column are not significantly different from each other at 5 % LSD.

#### 4.1.5.2. Survival of *S. zeamais* on *Parkia* and maize substrates under ambient environmental conditions

The study on the survival of *S. zeamais* on *Parkia* and maize substrates under ambient environmental conditions revealed significant differences ( $P < 0.05$ ) among the percentage survival of maize weevils on the various substrates. Survival of *S. zeamais* on *Parkia* substrates decreased over time while the survival stabilized with time on maize variety Volta local. The highest percentage survival recorded ( $94.5 \pm 1.55$ ) was on maize during the first week while *P. Pods* recorded the lowest percentage survival of weevils ( $0.7 \pm 0.75$ ) during week 2 (Table 2).

**Table 2. Mean survival of *S. zeamais* on *Parkia* and maize substrates under ambient environmental condition from Jan.-Feb., 2005.**

Substrates	Percentage survival $\pm$ S.E*		
	Week 1	Week 2	Week 3
Maize	$94.5 \pm 1.55^a$	$91.5 \pm 2.87^a$	$90.2 \pm 3.30^a$
<i>P. Pulp</i>	$78.2 \pm 3.9^b$	$3.0 \pm 1.0^b$	$0.0 \pm 0.0^b$
<i>P. Pods</i>	$69.0 \pm 2.42^c$	$0.7 \pm 0.75^b$	$0.0 \pm 0.0^b$
<i>P. Seeds</i>	$46.7 \pm 6.45^d$	$0.0 \pm 0.0^b$	$0.0 \pm 0.0^b$

Different *Parkia* substrates designated as *P. Pulp*, *P. Pods* and *P. Seeds*

\* Values are means of four replicates  $\pm$  standard error.

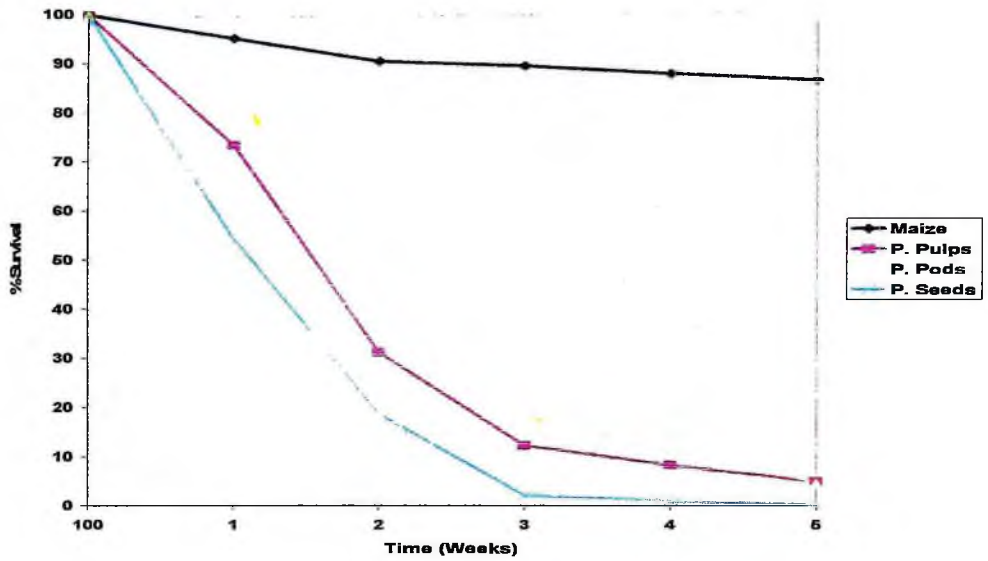
Means followed by same letter(s) in a column are not significantly different from each other at 5 % LSD.

#### 4.1.6. Discussion.

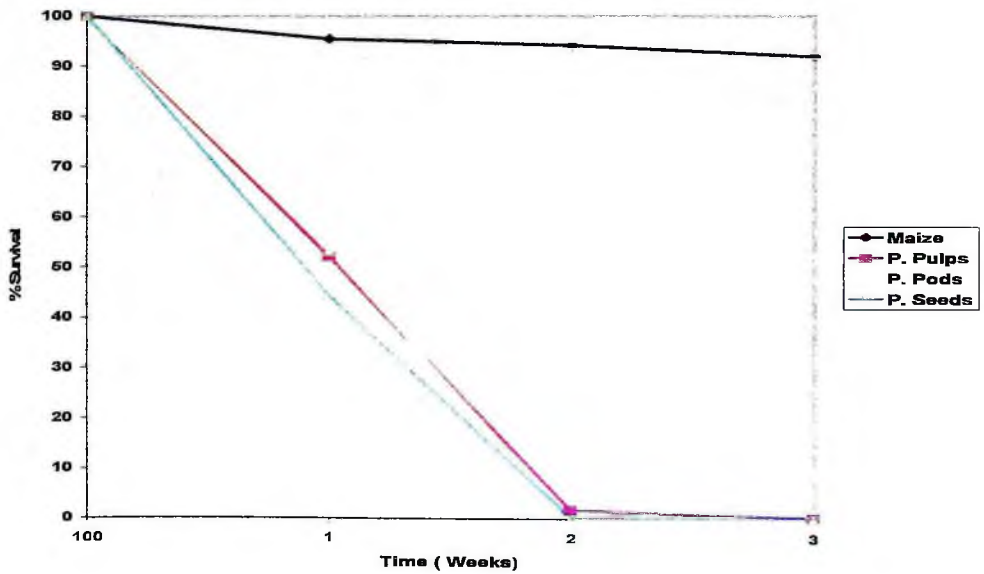
The present study showed that there were significant difference ( $P < 0.05$ ) in the percentage survival of *S. zeamais* under both field and laboratory conditions. Comparison of the two experimental environments showed that higher percentage of survival of *S. zeamais* was on maize, the survival of *S. zeamais* was decreasing at a fast rate till observations were terminated at the end of week three under ambient environmental conditions and week five under controlled conditions. These differences in the survival may not be attributed to environmental conditions and the reason are not clear. These were confirmed when the experiment was repeated for controlled environment (Figure 2) and ambient conditions (Figure 3); the differences in the survival followed similar trends to the previous experiments. On the other hand considerable level of mortality was recorded on *Parkia* substrates under both sets of conditions, with few *S. zeamais* adults surviving beyond second week under ambient environmental conditions and week five under controlled conditions. A possible reason for the observed mortality on *Parkia* substrates may be due to the presence of potentially toxic substances in the seeds and parkine in the pods. Hopkins (1983) reported the presence of parkine from pods of *P. biglobosa* which has similar physiological action to that of the alkaloids mimosine and physostigmine. It could also be due djenkolic acid and lectins present in the seeds. It may also be that *Parkia* substrates are nutritionally inferior for weevil survival and development. Cobbina

and Sabitti (1992) reported that raw *Parkia* seeds appear inferior in nutrient content than *Parkia* pods

**Figure 2 : Survival of *S. zeamais* on *Parkia* and maize substrates in an enviromental chamber in the laboratory (April- May, 2006)**



**Figure 3 : Survival of *S. zeamais* on *Parkia* and maize substrates under ambient enviromental conditions (April-May, 2005).**



## 4.2. Preference for *Parkia* and maize substrates by *S.zeamais*.

### 4.2.1. Introduction

Preference for a particular produce by an insect could be attributed to factors such as quality, texture and other physical or chemical characteristics of the produce. This is also related to the suitability of the produce for oviposition and development (Chijindu,2002). The use of preference test for studying choice between two or more plant species had been studied by different authors (Jermy,1966 ; Jermy *et al.*, 1968 ; Jermy and Szentesi,1978 ; Reddy *et al.*,2002). They all reported that substrates selection for oviposition and other behavioural activities, such as orientation and colonization are governed by two factors:(i) Feeding stimulant such as certain plant substances which include saccharide, amino acids, ascorbic acid etc, which evoke biting or feeding responses;(ii) Inhibitory factors such as the presence of feeding deterrents. *Sitophilus zeamais* adults show definite preference for grains on sections of maize cobs for egg deposition (Vowotor,1992). Genetics or physical factors may be responsible for weevil preference. Schoonhoven *et al.*(1976) reported that the physical factors that may cause maize kernel infestations include the presence of damaged kernels where the endosperm is exposed, and presence of seed-borne fungi on kernels which may create moisture differentials along the cobs and results in conditions that are conducive for insect infestations. In this study, tests for preference was conducted under controlled and ambient conditions to evaluate the relative preference of adults *S. zeamais* for *Parkia* and maize substrates.

#### 4.2.2. Materials and Methods

Ten grammes of the four treatment (*Parkia* seeds, *Parkia* pulp, *Parkia* pods and maize variety Volta local) were placed on a filter paper inside separate Petri dishes (9cm diameter). The Petri dishes were randomly arranged in a circular form on a plastic tray (104cm x 7cm x 5cm). The trays were covered with muslin cloth. Four replicates of such trays were set up with the experiment being repeated twice. Forty, 7-14 day old unsexed adults *S. zeamais* were introduced in the centre of the trays. The set up was observed for a total of 72 hours (Calvitti and Remotti, 1998 ; Reddy *et al.*, 2002). Preferences were assessed based on the number of weevils found during each 24-hour interval on each substrate. The whole set up was maintained in an environmental chamber in the laboratory (See Plate 10). Another set-up, similar to the previous one, was prepared and maintained in wooden cages (each cage, measuring 61cm x 45cm x 41cm) under ambient conditions (See Plate 11).



**Plate 10: Experimental set up for preference tests in an environmental chamber in the laboratory.**



**Plate 11: Experimental set up for preference tests under ambient conditions in the Screen house**

#### **4.2.3. Data collection**

The number of weevils found on each experimental unit after every 24-hours was recorded and the data were collected for 72 hours.

#### **4.2.4. Data analysis**

Data on tests for preference were transformed using square root of  $(x + 1)$  and subjected to analysis of variance, and the mean values were separated by LSD.

#### 4.2.5. Results:

##### 4.2.5.1. Preference test under controlled conditions

The orientation and colonization responses of maize weevils in free choice tests shown in (Table 3) revealed that, significantly more ( $P < 0.05$ ) weevils were recorded on maize variety Volta local than on *Parkia* substrates under the controlled conditions. Some 24-72 hours after introduction, higher numbers of weevils were recorded on maize than on *Parkia* substrates (Table 3). Statistically, the number initially recorded on maize was not different ( $P > 0.05$ ) from the number recorded on *P. Pulp*. Also, observations made at both 48 and 72 hours intervals revealed that the number of weevils recorded followed a similar trend to the previous observation with significantly ( $P < 0.05$ ) more weevils recorded on maize compared to *Parkia* substrates (Table 3).

**Table 3. Mean number of *S.zeamais* on maize and *Parkia* substrates under controlled conditions.**

Substrates	Mean number of <i>S.zeamais</i> $\pm$ S.E*		
	24 hours	48 hours	72 hours
Maize	9.0 $\pm$ 2.00 <sup>a</sup>	25.2 $\pm$ 9.99 <sup>a</sup>	38.5 $\pm$ 9.00 <sup>a</sup>
<i>P. Pulp</i>	4.7 $\pm$ 1.49 <sup>ab</sup>	7.2 $\pm$ 2.36 <sup>b</sup>	10.5 $\pm$ 4.56 <sup>b</sup>
<i>P. Pods</i>	3.2 $\pm$ 0.75 <sup>b</sup>	3.2 $\pm$ 1.65 <sup>b</sup>	4.2 $\pm$ 1.38 <sup>b</sup>
<i>P. Seeds</i>	3.5 $\pm$ 1.71 <sup>b</sup>	5.2 $\pm$ 1.93 <sup>b</sup>	6.2 $\pm$ 1.44 <sup>b</sup>

Different *Parkia* substrates designated as *P. Pulp*, *P. Pods* and *P. Seeds*

\* Values are means of four replicates  $\pm$ standard error

Means followed by same letter(s) in a column are not significantly different from each other at 5 % LSD.

#### 4.2.5.2. Preference test under ambient environmental conditions

In free-choice tests, there were significantly more ( $P < 0.05$ ) weevils recorded on maize variety Volta local than on *Parkia* substrates under ambient environmental conditions (Table 4). When data were examined 24 hours after the introduction, significant differences ( $P < 0.05$ ) were observed in the mean number of weevils recorded on some of the substrates used. *P. Pods* had the least mean number of insects ( $4.5 \pm 1.66$ ) recorded, while the highest mean number of ( $18.5 \pm 1.76$ ) was recorded on maize variety Volta local. After 48 hours, it was observed that the mean number of weevils recorded followed a similar trend as that of 72 hours. Significantly ( $P < 0.05$ ) more weevils were recorded on maize variety Volta local than on *Parkia* substrates (Table 4).

**Table 4. Mean number of *S.zeamais* on maize and *Parkia* substrates under ambient environmental conditions.**

Substrates	Mean number of <i>S.zeamais</i> $\pm$ S.E*		
	24 hours	48 hours	72 hours
Maize	18.5 $\pm$ 1.76 <sup>a</sup>	38.50 $\pm$ 0.65 <sup>a</sup>	39.50 $\pm$ 0.29 <sup>a</sup>
<i>P. Pulp</i>	12.5 $\pm$ 3.48 <sup>ab</sup>	7.2 $\pm$ 2.84 <sup>b</sup>	8.5 $\pm$ 2.02 <sup>b</sup>
<i>P. Pods</i>	4.5 $\pm$ 1.66 <sup>b</sup>	3.0 $\pm$ 0.82 <sup>b</sup>	3.5 $\pm$ 1.15 <sup>b</sup>
<i>P. Seeds</i>	6.2 $\pm$ 1.55 <sup>b</sup>	6.0 $\pm$ 1.58 <sup>b</sup>	4.0 $\pm$ 0.58 <sup>b</sup>

Different *Parkia* substrates designated as *P. Pulp*, *P. Pods* and *P. Seeds*.

\* Values are means of four replicates  $\pm$  standard error

Means followed by same letter(s) in a column are not significantly different from each other at 5 % LSD

#### 4.2.6. Discussion

A comparison of the orientation and colonization responses of the *S. zeamais* under ambient and controlled conditions showed that initially there was significant difference in the number of weevils recorded on both *Parkia* and maize variety Volta local substrates, and with time significantly ( $P < 0.05$ ) more weevils were recorded on the maize variety Volta local compared to the *Parkia* substrates. The test for feeding preference lasted for 72 hours, which conforms to observation by Calvitti and Remotti (1998) that polyphagous insects need at least 72 hours to make final choice. Therefore, quick recognition to morphological and olfactory cues are important determinants of host choice than exploratory feeding assessment of hosts. Accordingly, greater feeding and oviposition would be expected on hosts that are more attractive for initial feeding than those suitable for long time survival. Another explanation of the choice appears to be related to a predominant reaction to odour and taste of the food item or that of both the odour and taste of the food item and make it easier for an individual to make a choice. High degree of colonization exhibited by the adult weevils for maize may be attributed to that. Niewiada *et al.*(2005) reported that weevils can recognize a food by the qualitative and quantitative chemical composition of the grain testa and may be one possible reason for the high colonization of the maize kernels.

### **4. 3. Oviposition of *S. zeamais* on *Parkia* and maize substrates**

#### **4. 3.1. Introduction**

The oviposition behaviour of *Sitophilus* spp. has been studied under different conditions of relative humidity and temperature on different varieties of maize and other cereals such as rice, sorghum and wheat. Many studies on the biology and behaviour of *Sitophilus* spp. are mostly on *S. granarius* and *S. oryzae* (Richards, 1947 ; Segrove,1951 ; Longstaff,1981 ; Danho *et al.*, 2002;). Insect oviposition behaviour is an important contributor to the fitness of insects because of the consequent effect on the number and quality of offspring (Smith, 1986 ; Honek,1993 ; Stejskal and Kucerova,1996). In holometabolous insects, where the immature have restricted movements, the oviposition behaviour of adults and larval development in the host are decisive factors in terms of host range (Wasserman and Futuyma,1981 ; Jansen and Nylin,1997; Carrière,1998). There are many factors that may influence the oviposition of insects on a specific host, such as morphology (Johnson and Kistler, 1987), nutritional quality, host abundance (Jansen and Nylin,1997 ; Barros and Zucoloto, 1999), places free of predators (Bernays and Graham,1988) and competition (Siemens *et al.*,1991). Oviposition behaviour therefore varies according to the insect species and strain, population density, environmental conditions, food, age and size of the individual (Stejskal and Kucerova, 1996). This study was undertaken with a view of understanding the oviposition behaviour of *S. zeamais* on *Parkia* and maize substrates.

#### 4. 3. 2. Materials and Methods

Tests for oviposition were conducted both at the Entomology laboratory and in the Screen.house at Sinna Garden. Before introduction of test insects, the moisture content of the *Parkia* and maize substrates were determined using a Digital Grain master (Protimeter PLC., England). The moisture content of substrates under the controlled conditions were: *Parkia* seeds (15.71%), *Parkia* pods (16.21%), *Parkia* pulp (18.10%) and maize variety Volta local (12.10%). The moisture content of substrates under ambient conditions were *Parkia* seeds (16.00%), *Parkia* pods (17.70%), *Parkia* pulp (17.50%) and maize variety Volta local (11.80%). One hundred grammes of each treatment (*Parkia* seeds, *Parkia* pulp, *Parkia* pods and maize variety Volta local) were put into each of four glass jars, which were replicated four times and one hundred, 7–14 day old unsexed adults *S. zeamais* were introduced into each glass jar to oviposit for 7 days. The experimental treatments were randomly arranged on shelves in a completely randomized design and maintained under controlled conditions. Another set of treatments similar to the previous experiment was also set up and maintained in wooden cages under ambient environmental conditions. At the end of the oviposition period (7 days) all the adult insects were sieved out with an Impact Test Sieve mesh size of 710 microns.

#### **4.3.3. Data collection**

Egg counts were based on the assumption that each egg-plug covered only one egg and each egg was covered by one plug (Sharifi,1972 ; Vowotor,1992). After oviposition, the shelled kernels were stained with acid fuschin, using procedure described by Sharifi (1972). Excess water was removed from the stained grains by spreading and drying them in a layer of tissue paper for 1-day in the laboratory and the number of eggs laid were examined under illuminated stereo microscope. Eggs plugs stained deep cherry red, differently from mechanical injuries which stained lighter. Counting of the eggs started 1-day after the termination of the egg laying period and continued everyday thereafter until all eggs were counted. Where counting could not be completed on kernels in a day, the uncounted kernels were put into glass jar and deep frozen to arrest further development. No eggs-plug was seen on the *Parkia* substrates, so it was assumed that no egg was laid on the *Parkia* substrates.

#### **4.3.4. Data analysis**

Data collected on the number of eggs laid on maize were analysed using descriptive statistics.

#### 4.3.5. Results and Discussion

The study on oviposition showed that the mean number of eggs laid on maize under controlled conditions was significantly ( $P < 0.05$ ) higher (114.5) than the number under ambient conditions (94.75). However, no eggs were laid on the *Parkia* substrates under both set of conditions. The results of this investigation have demonstrated that oviposition was significantly affected by temperature and relative humidity. Optimum temperature favours the large number of eggs recorded under controlled conditions than ambient conditions. This agrees with Birch (1944), Richards (1947) and Howe (1952) that optimum temperature for eggs laying was around 25°C. It was observed from the study that *S. zeamais* tended to cluster eggs on kernels, leaving many kernels untouched. Legg *et al.*(1987) reported that the distribution of maize weevil eggs on maize kernels was aggregated and that eggs aggregation generally increased with increasing maize weevil density and duration of oviposition/feeding period although the specific response depended on grain density. Reasons for clustering of eggs on kernels are not clear. However, it was reported by Urrelo and Wright (1989) that egg aggregation behaviour of the female weevils enhances the fitness of larvae and emerged F1 progeny. This behaviour of the female weevil is, however, maladaptive where multiple oviposition occurred in the maize or wheat kernel. Maize weevils may be guided by chemosensory factors, in addition to physical factors in selecting a favourable oviposition site on the maize kernel (Vowotor,1992). The choice of a favourable oviposition site would enhance faster development by the

larvae that hatch, because they would have easier access to more nutritious materials within the kernel. The reason why oviposition and/or feeding were inhibited on *Parkia* substrates is not clear. It could be due to either physical properties of the substrates such as pericarp characteristics (testa) or hardness of seeds. Locatelli and Limonta (1998) reported that the presence of pericarp obstruct both the egg laying and emergence of grain weevils (*Sitophilus* spp.). Therefore, the maize weevils may find it difficult to gain a grip on the seeds, pulp or the pods, and thus have inadequate leverage for feeding and/or oviposition. From the foregoing, it is evident the strain of *S. zeamais* used in the present studies was unable to lay eggs on *Parkia* substrates under both set of conditions, which may be due to antixenosis or antibiosis.

#### **4.4. Development of *S.zeamais* on *Parkia* and maize substrates**

##### **4.4.1. Introduction**

Development of any insect from egg to adult depends on a number of factors such as temperature, humidity, the nature of substrate, and the type and quality of grain being infested, which may be related and known to affect the development of insects (Haines,1991 ; Chijindu,2002). The development of *S. zeamais* on maize ranges from about 35 days under optimal to over 110 days at sub-optimal conditions of temperature and relative humidity (Richards,1947 ; Haines,1991). The mean developmental periods of *S. zeamais* at 27°C and 70% r.h. have been shown to vary from 31 to 37 days, on different maize varieties (Birch,1944 ; Howe,1952 ; Longstaff,1981 ; Haines,1991). Vowotor *et al.*(1994) reported that the developmental period of *S. zeamais* on shelled grains was 42 days and on ears with or without husks was 52 days. This study was conducted under field and laboratory conditions with a view to compare development of *S. zeamais* on *Parkia* and maize substrates.

##### **4.4.2. Materials and Methods**

The development of insects were conducted both at the Entomology Laboratory and in the Screen house at Sinna garden. Before infestation, the moisture content of the substrates was determined using a Digital Grain master (Protimeter PLC., England). The moisture contents under both set of conditions were: *Parkia* seeds (18.25%), *Parkia* pulp (20.10%), *Parkia* pods (14.70%) and maize variety Volta

local (13.50). One hundred grammes of each treatment (*Parkia* seeds, *Parkia* pulp, *Parkia* pods and maize variety Volta local) were put into each of four glass jars which were replicated four times and one hundred, 7–14-day old unsexed adults *S. zeamais* were introduced into each glass jar to oviposit for 7 days. The experimental treatments were randomly arranged in a completely randomized design and maintained in an environmental chamber in the laboratory. Another set of treatments similar to the previous experimental set-up was prepared and maintained in wooden cages under ambient environmental conditions. After 7 days of oviposition, all the adult insects were sieved out with an Impact Test Sieve with mesh size of 710 microns, after which all jars were left undisturbed until adult emergence of the F<sub>1</sub> generation.

#### **4.4.3. Data collection**

Emerged adults from maize were removed on a daily basis and their numbers counted and recorded until all of the F<sub>1</sub> generation had emerged. The weight of adults emerging from the substrate was also taken using a sensitive Mettler balance Model 870 KERN. As for *Parkia* substrates, nothing emerged from them, so developmental period and mean weight could not be collected.

#### 4.4.4. Data analysis

Data on developmental period and mean weight of adults emerging from *Parkia* substrates were not included in the statistical analysis. Only the developmental period and mean weight of adults emerging from maize were determined.

#### 4.4.5. Results and Discussion

The mean developmental period on maize under controlled conditions was significantly ( $P < 0.05$ ) shorter (41.2 days) than the period under ambient conditions (47.0 days). Comparison of the developmental period under controlled and ambient conditions showed that more weevils developed in the culture placed in controlled conditions than those kept under ambient condition, although no significant differences were observed in the monthly records of temperature and relative humidity under both set of conditions during these periods. These differences in the development period may be due to more satisfactory temperature and relative humidity in the controlled conditions that favoured more weevil development than under ambient condition. The development period observed in this study fell within the range reported by several authors. Schoonhoven *et al.* (1974) showed that the development period for weevils reared on maize kernels and pellets made from maize kernel fractions at 27°C and 68% r.h. varied from 42.9-48.9 days. Similarly, Kossou *et al.* (1993) and Vowotor *et al.* (1994) found that development of *S. zeamais* was 31.5 days- 52.0 days from egg hatch to adult emergence at 25°C and 70–75% r.h. depending on whether it is

shelled grains or unshelled; husked or dehusked cobs, respectively. *Sitophilus zeamais* did not reproduce at all on *Parkia* substrates under both sets of conditions. It is clear from the present investigations that *S. zeamais* does not lay eggs on *Parkia* substrates, eggs were not hatched nor were larvae able to survive (no dead larvae were found in any of the experimental units). It was clear from this investigation that *Parkia* substrates is not a suitable host for the strain of *S. zeamais* used in these studies.

#### 4.4.6. Adult weight

The mean weight of *S. zeamais* F1 adults that emerged from maize variety Volta local under the controlled conditions (3.4mg) was not different ( $P > 0.05$ ) from what was obtained under ambient environmental conditions (2.8mg). The mean weight in controlled conditions was slightly heavier than those under ambient conditions. The results of this study are similar to that observed by Adams (1976) who reported the mean weight of 3.1mg for *S. zeamais* adults developing in 13.5% moisture content maize at 27°C and 70% r.h. Similarly, Vowotor (1992) recorded adult weights of 3.07-3.41 mg from different varieties of maize and 3.10-3.26 mg for unshelled and shelled kernels in different storage forms in a laboratory at 25±2°C and 70± 2% r.h. Danho *et al.*(2002) reported the mean weight of 3.16 and 3.05 mg for female and male weevils developing in a laboratory at 30°C and 70% r.h.

## CHAPTER FIVE

### 5.0.CONCLUSION AND RECOMMENDATIONS

#### 5.1. Conclusion

Suitability studies on *Parkia* pods, pulp and seeds as alternative breeding medium for the survival, oviposition and development of *S. zeamais* were conducted under two sets of conditions, namely an environmental chamber in the laboratory and ambient conditions in the Screen house. The results revealed that *Parkia* pods, pulp and seeds are not suitable host for the strain of *S. zeamais* used in the present studies. Since host suitability is an ability to survive, reproduce and grow after feeding on a host (Teixeira and Zucoloto, 2003) and only survival were observed on the *Parkia* pods, pulp and seeds, the results of these studies indicate that *Parkia* pods, pulp and seeds may not act as an alternate hosts to *S. zeamais*. During the course of the study, it was observed that some substances in the seeds (such as djenkolic acid and lectins) and pods (such as parkine) could be repelling the weevils and preventing them from settling on the them.

From this, no conclusion can be drawn that *Parkia* pods, pulp and seeds may act as alternate hosts for *S. zeamais* and investigation needed to be undertaken to determine the actual factors responsible for the unsuitability or unacceptability of *Parkia biglobosa* as a host for *S. zeamais*.

## 5.2. Recommendations

From this study, it is suggested that a better understanding of the biology and behaviour of *S. zeamais* in relation to *Parkia* pods, pulp and seeds will assist in the development of improved management practices for the control of this pest and so reduce heavy losses caused by this pest both in the field and storage. Further work needs to be done to investigate oviposition deterrents/inhibitors and even the potential of *Parkia* substrates as botanical insecticides because of the repellent effects that were observed during the course of the study.

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**APPENDICES****APPENDIX 1 : Analysis of variance for relative preference of *Sitophilus zeamais* for *Parkia* and maize substrates.****(ambient conditions)****APPENDIX 1.1(a): Analysis of variance for twenty-four hours**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal.</b>	<b>F. pr.</b>
Treatments	3	488.19	162.73	8.01	0.003
Residual	12	243.75	20.31		
<b>Total</b>	<b>15</b>	<b>731.94</b>			

**APPENDIX 1.2(b): Analysis of variance for forty-eight hours**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F. cal.</b>	<b>F. pr.</b>
Treatments	3	3321.69	1107.23	95.08	<.001
Residual	12	139.75	11.65		
<b>Total</b>	<b>15</b>	<b>3461.44</b>			

**APPENDIX 1.3(c): Analysis of variance for seventy-two hours**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F. cal.</b>	<b>F. pr.</b>
Treatments	3	3562.750	1187.583	212.70	<.001
Residual	12	67.000	5.583		
<b>Total</b>	<b>15</b>	<b>3629.750</b>			

**(Controlled conditions)****APPENDIX 1.4: Analysis of variance for twenty-four hours**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F. cal.</b>	<b>F pr.</b>
Treatments	3	85.250	28.417	2.93	0.077
Residual	12	116.500	9.708		
<b>Total</b>	<b>15</b>	<b>201.750</b>			

**APPENDIX 1.5: Analysis of variance for forty-eight hours**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F. cal.</b>	<b>F pr.</b>
Treatments	3	1226.2	408.7	3.66	0.044
Residual	12	1341.2	111.8		
<b>Total</b>	<b>15</b>	<b>2567.4</b>			

**APPENDIX 1.6: Analysis of variance for seventy-two hours**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F. cal.</b>	<b>F. pr.</b>
Treatments	3	3058.3	1019.4	9.65	0.002
Residual	12	1267.5	105.6		
<b>Total</b>	<b>15</b>	<b>4325.8</b>			

**APPENDIX 2: Analysis of variance for the survival of *Sitophilus zeamais* on *Parkia* and maize substrates from Jan.-Feb., 2005 .**

**(Controlled conditions)**

**APPENDIX 2.1: Analysis of variance for week one**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal.</b>	<b>F pr.</b>
Treatments	3	3849.69	1283.23	20.08	<.001
Residual	12	766.75	63.90		
<b>Total</b>	<b>15</b>	<b>4616.44</b>			

**APPENDIX 2.2: Analysis of variance for week two**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal.</b>	<b>F pr.</b>
Treatments	3	13862.2	4620.8	24.80	<.001
Residual	12	2235.5	186.3		
<b>Total</b>	<b>15</b>	<b>16097.7</b>			

**APPENDIX 2.3: Analysis of variance for week three**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal.</b>	<b>F pr.</b>
Treatments	3	20789.2	6929.7	65.06	<.001
Residual	12	1278.2	106.5		
<b>Total</b>	<b>15</b>	<b>22067.4</b>			

**APPENDIX 2.4: Analysis of variance for week four**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal</b>	<b>F pr.</b>
Treatments	3	23085.19	7695.06	91.04	<.001
Residual	12	1014.25	84.52		
<b>Total</b>	<b>15</b>	<b>24099.44</b>			

**APPENDIX 2.5: Analysis of variance for week five**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal</b>	<b>F pr.</b>
Treatments	3	24950.750	8316.917	1028.90	<.001
Residual	12	97.000	8.083		
<b>Total</b>	<b>15</b>	<b>25047.750</b>			

**(Ambient conditions)****APPENDIX 2.6: Analysis of variance for week one**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal.</b>	<b>F. pr.</b>
Treatments	3	4767.25	1589.08	24.37	<.001
Residual	12	782.50	65.21		
<b>Total</b>	<b>15</b>	<b>5549.75</b>			

**APPENDIX 2.7: Analysis of variance for week two**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal.</b>	<b>F. pr.</b>
Treatments	3	24454.687	8151.563	830.73	<.001
Residual	12	117.750	9.813		
<b>Total</b>	<b>15</b>	<b>24572.437</b>			

**APPENDIX 2.8: Analysis of variance for week three**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal.</b>	<b>F. pr.</b>
Treatments	3	24435.19	8145.06	747.54	<.001
Residual	12	130.75	10.90		
<b>Total</b>	<b>15</b>	<b>24565.94</b>			

**APPENDIX 3 : Analysis of variance for the survival of *Sitophilus zeamais* on *Parkia* and maize substrates from April- May, 2005 .**

**(Controlled conditions)**

**APPENDIX 3.1: Analysis of variance for week one**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal.</b>	<b>F pr.</b>
Treatments	3	3757.19	1252.40	20.40	<.001
Residual	12	736.75	61.40		
<b>Total</b>	<b>15</b>	<b>4493.94</b>			

**APPENDIX 3.2: Analysis of variance for week two**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal.</b>	<b>F pr.</b>
Treatments	3	12079.2	4026.4	22.94	<.001
Residual	12	2106.3	175.5		
<b>Total</b>	<b>15</b>	<b>14185.4</b>			

**APPENDIX 3.3 : Analysis of variance for week three**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal.</b>	<b>F pr.</b>
Treatments	3	19098.7	6366.2	58.00	<.001
Residual	12	1317.2	109.8		
<b>Total</b>	<b>15</b>	<b>20415.9</b>			

**APPENDIX 3.4: Analysis of variance for week four**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal.</b>	<b>F pr.</b>
Treatments	3	19771.5	6590.5	64.43	<.001
Residual	12	1227.5	102.3		
<b>Total</b>	<b>15</b>	<b>20999.0</b>			

**APPENDIX 3.5: Analysis of variance for week five**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal.</b>	<b>F pr.</b>
Treatments	3	20682.69	6894.23	271.92	<.001
Residual	12	304.25	25.35		
<b>Total</b>	<b>15</b>	<b>20986.94</b>			

**(Ambient conditions)****APPENDIX 3.6: Analysis of variance for week one**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal.</b>	<b>F pr.</b>
Treatments	3	6394.3	2131.4	11.78	<.001
Residual	12	2171.5	181.0		
<b>Total</b>	<b>15</b>	<b>8565.7</b>			

**APPENDIX 3.7: Analysis of variance for week two**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal.</b>	<b>F pr.</b>
Treatments	3	26280.69	8760.23	681.51	<.001
Residual	12	154.25	12.85		
<b>Total</b>	<b>15</b>	<b>26434.94</b>			

**APPENDIX 3.8: Analysis of variance for week three**

<b>Source of variation</b>	<b>d.f.</b>	<b>s.s.</b>	<b>m.s.</b>	<b>F.cal.</b>	<b>F pr.</b>
Treatments	3	25346.19	8448.73	730.70	<.001
Residual	12	138.75	11.56		
<b>Total</b>	<b>15</b>	<b>25484.94</b>			