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ECOLOGY, LIFE CYCLE AND WAYS OF SUBJUGATING THE MAIZE WEEVIL *Sitophilus zeamais* IN STORAGE

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ABSTRACT

Maize, also known as corn, is a staple food in Africa, particularly Nigeria. It is a very rich source of highly digestible carbohydrate; which if eaten in the immature state, provides useful quantities of Vitamin C. The yellow grain varieties contain Vitamin A. Fresh maize can be boiled, roasted or cooked with beans and eaten. It can also be grounded and prepared into paste for making palp; or fried in oil into 'corn-cake'('Pekere' in the Yoruba part of Nigeria). Very dry maize can be powdered into 'flour' which can be prepared into various foods, such as Semovita, Bread and various snacks; while dry grains of a particularly variety that explodes when heated, can be roasted into a popular refreshment known as 'Popcorn'. Industrially, maize can be used for the production of cereal baby foods, corn-oil, glucose, gum, starch and alcohol. The grains constitute the major ingredient in the production of livestock feed called mash, particularly, for poultry and pigs. The green leaves of maize plant can be fed as fodder to livestock, or in the form of hay or silage. Sale of maize grains or its products and by-products, constitutes a major trade in our local markets and the grain board; forming an important source of income and livelihood of our people. In spite of the great value of maize, its availability and utilization in many countries, particularly Nigeria, have been impaired due to seed damage by pests; particularly, the larvae of the maize weevil (Sitophilus zeamais) Motschulsky. Attack by this pest begins in the field and continues in storage, causing substantial damage to stored grains as the pest population rapidly increases. Greater attention therefore, should be paid to the crop during storage in order to make its grains available for use when needed. This paper therefore, examined the life cycle of the maize weevil, Sitophilus zeamais, and discussed ways of subjugating the insect, for a sustainable maize grains storage and utilization.

Keywords: Sitophilus zeamais, Maize grains, Depredation, Subjugation

INTRODUCTION

The maize plant *Zea mays* (Motschulsky), is an important non-branching annual cereal (starchy grain) crop in the grass family *Poaceae*. It belongs to the order *Poales,* sub-family *Panicoideae* and tribe *Andropogoneae*, It is a caryopsis and one of the oldest and mostly widely cultivated world cereals, with 332 million metric tons grown annually in the United States alone (Arthur, et al., 1998).

Maize, also known as corn, was introduced into Africa by the Portuguese in the 16th century, but has now become the most important staple food crop in many parts of Africa, particularly Nigeria (Longe and Ofuya, 2009). It provides food for man and feed for livestock. In Mexico where it originated, virtually every dish in Mexican cuisine uses maize

It is a very rich source of highly digestible carbohydrate; which if eaten in the immature state, provides useful quantities of Vitamin C. The yellow grain varieties also contain Vitamin A (Anyanwu et al., 1998). Fresh maize can be boiled, roasted or cooked with beans and eaten. Maize grains can also be grounded and prepared into paste for making palp; or fried in oil into 'corn-cake' (called 'Pekere' in Yorubaland). Very dry maize can be powdered into 'flour' which can be prepared into various foods, such as Semovita, Bread and various snacks; while dry grains of a particularly variety, can be roasted into a popular refreshment known as 'Popcorn'. The grains constitute the major ingredient in the production of livestock feed (mash), particularly, for poultry and pigs. The green leaves of maize plant can also be fed as fodder to livestock, or in the form of hay / silage. The sale of maize grains or its products / by-products, constitutes a major trade in our local markets and the grain board; forming an important source of income and livelihood of our people.

Industrially, maize can be used for the production of cereal baby foods, corn-oil, glucose, gum, starch and alcohol. Starch from maize can also be made into plastics, fabrics, adhesives, and many other chemical products. The corn steep liquor, a watery byproduct of maize wet milling process, is widely used in the biochemical industry and research as a culture medium to grow many kinds of microorganisms (Manueke, et al., 2015). Maize is increasingly being used as a feedstock for the production of ethanol fuel The ethanol is mixed with gasoline to decrease the amount of pollutants emitted when used to fuel motor vehicles. Approximately 40% (130 million tons) of the 332 million metric tons of maize grown annually in the United States is used for corn ethanol production (Asanov, 1990). Maize is widely used in Germany as a feedstock for biogas plants, while its cobs are also used as a biomass fuel source. Chrysanthemin found in purple corn is used as a food colouring.

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DAMAGE DONE BY *Sitophilus zeamais* TO MAIZE GRAINS

In spite of the great value of maize, its availability and utilization in many countries, particularly Nigeria, have been impaired due to seed damage by pests; particularly, the larvae of the maize weevil *(Sitophilus zeamais)* Motschulsky (Jackal and Daoust, 1986). Attack by this pest begins in the field and continues in storage, causing substantial damage to stored grains as the pest population rapidly increases (Ofuya, 2003). Damage done to stored maize by the weevil in the tropics is enormous (Compton and Sherington, 1999). Adesuyi (1997) reported that about 24.7% of stored maize in a traditional storage structure was lost after 6months of storage through attack by the maize weevil, which feeds on the germ of maize seeds.

Adult weevils and larvae feed on undamaged maize grains and reduce them to powdery form. (Adedire, 2001) As soon as infestation commenced, the weevil continues to reproduce and destroy the grains in the store. The developmental activities of the weevil often lead to severe powdering and tainting of the grains with their excrements. The infested grains become perforated and are often rendered susceptible to caking and mould infection, thereby reducing their market value and germination potentials. The destructive effect of the weevil is more pronounced in unprotected shelled dried maize and maize on cob, stored in cribs, silos etc.

It is clear from the fore-going that depredation of stored maize grains by *Sitophilus zeamais* is a major constraint to a successful maize production and utilization in the tropics (Ofuya, 2003) and a major factor militating against the crop's availability and food security in Nigeria (Lale, 2001). It is imperative therefore, that greater attention should be paid to the crops during storage in order to make them available for use throughout the year. Any reduction in loss between harvest and consumption would increase the availability of maize grains and ensure a successful millennium development goal on food security. This paper therefore, examined the life cycle of the maize weevil, *Sitophilus zeamais* and discussed ways of subjugating the pest, to ensure a sustainable maize grains storage and availability in the market.

BASELINE STUDIES OF THE MAIZE WEEVIL (*Sitophilus zeamais*)

- Kingdom: Animalia
- Phylum: Arthropoda
- Class: Insecta
- Order: Coleoptera
- Family: Curculionidae
- Sub-family: Dryophthorinae
- Genus: Sitophilus
- Species: *Sitophilus zeamais*

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DESCRIPTION AND EXTERNAL SEX CHARACTERISTICS :

The maize weevil, *Sitophilus zeamais*, is a small agricultural insect pest in the beetle family, Curculionidae (snout beetles). The adult maize weevil is characterized and often distinguishable from all other stored product pests by its long rostrum, which is a forward snout-like extension of the head and which carries the mouthparts in a position that is ideal for penetrating commodities. Possession of a long rostrum is the main diagnostic feature of all curculionids called weevils (Odeyemi & Daramola, 2000; Adedire, 2001). The rostrum of the male is distinctly shorter and wider than that of the female, and while that of the female is smooth and shinning and that of the male is rough (Adedire, 2000).

Adult S. *zeamais* is quite small, measuring 3-5mm in length (NRI, 1996; Lale, 2002). It is dark-brown or black in colour with four distinct pale reddish-brown oval markings, (spots), or patches on the elytra (Ojomu, 1976; Appert, 1987). The head has capitate (rounded) and elbowed antennae with 8 segments that are often carried in an extended position when the insect is walking. The fore-wings are hard with well developed metathoracic flight wings and a prothorax with circular punctures and which gives the adult weevil a greater ability and tendency to fly to the ripening crop in the field and establish an infestation in the grains before harvest, than other species (Ojomu, 1976; Appert, 1987; Odeyemi & Daramola, 2000).

Fig.1: *Sitophilus zeamais* in pix

ORIGIN, DISTRIBUTION AND HOST RANGE:

Sitophilus zeamais is a serious cosmopolitan primary pest of sound and wholesome grains of stored maize in both tropic and temperate regions of the world. In Nigeria, the insect occurs throughout the year; where it is secondarily found attacking other crops such as rice, guinea corn *(Sorghum),* yam products in the store, groundnut, millet, cassava flour, dry cocoyam and beniseed (Sesame) (NR1, 1996).

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BIOLOGY, ECOLOGY AND BEHAVIOUR *(LIFE HISTORY);*

Oviposition / Larvae Development:

Infestation (Egg-laying) starts in the field on maize cobs, where the shucks do not encase the head properly or in which graminaceous borers have made holes. The adult female bites or chews into the maize grain and makes a cavity inside them. It deposits an egg in each of the holes made and later seals them with a hard secretion called 'egg plug' (Lale 2001). The adults are long-lived (several months to one year). Eggs are laid throughout most of the adult life, although 50% may be laid in the first 4-5 weeks

S. zeamais eggs hatch in about 6days at a temperature of 25°C. The development of the larvae, as well as pupation takes place inside the grain, and then the adult emerges. The female may lay between 300 and 400 eggs in its life span. The eggs hatch into larvae commonly called *grubs* and which feed exclusively inside the grain, excavating a tunnel as it develops. The larval stage is the most destructive stage of the weevil and accounts for most of the damage done to the grain. The larvae are plump, cruciform (cross-shaped), Creamy-white in appearance and apodous (legless); hence, they are immobile. Mature larvae measures about 4mm in length (Hill, 1983). There are four larval instars and pupation occurs at about 25days after eggs were laid. The eggs, larvae and pupae are not normally seen because they develop inside intact grains.

Generation Time:

The complete development time and adult emergence of *S. zeamais* from seeds under optimal conditions of 30°C and 70% relative humidity (r.h.), occurs between 35-60 days after eggs have been laid; but may be up to 110 days at sub-optimal conditions (Odeyeml & Daramola, 2000). After pupation, the newly developed adult chew its way out of infested grain through a fairly large characteristic circular emergence hole made on the outer coat of the grain. Unlike *C. maculatus* adults which do not feed, adults of *S. zeamais* grub or feed inside the maize grains; leaving powdery residues afterwards. This feeding habit helps to enhance long-life in the insect. The longevity period, is up to 5 months (Adedire, 2001) or even 1 year (Lale, 2002). Their infestation leads to considerable loss in weight, deterioration of quality and promotes rapid growth of micro-flora. The weevils are unique because their attack tends to increase the moisture content of infested cereal grains to appreciable levels. Emerged adults are good fliers (Adedire, 2001). They re-enter holed maize seeds at will, either to feed or to lay eggs. When the adults emerge, the females move to a high surface and release sex pheromones. Males are then attracted to this pheromone (Mason, 2003).

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MEASURES OF SUBJUGATION (PREVENTION & CONTROL) OF *Sitophilus zeamais*

The basic principle of pest control involves a high standard of hygiene, minimum use of chemicals to reduce incidence of residues, selection for resistance to environmental hazards, general overhead costs and the use of methods that give as complete a kill as possible (Odeyemi, 2003).

In the control of curculionids, preventive and curative measures complement each other; and this is necessary for long-term efficacy of the control measures adopted. The degree of success observed in maize production, is a function of the level of pest control.

To achieve an effective pest management status therefore, several measures or methods have been put in place or adopted by researchers and grain farmers; such as proper sanitation and good warehouse management (as preventive measures); the use of conventional insecticides (chemical control); physical control practices; good cultural measures; the use of natural enemies or predators (biological control); using resistant crop varieties; the use of inert materials and using plant materials such as extracts and oils, contact powders, fumigants, repellants and anti-feedants.

PREVENTIVE MEASURES (General Sanitation and Warehouse Management):

This consists of the careful observance of all hygiene measures, with which all other measures are of no effect and uneconomical (Ofuya, 2001). Preventive measures with regards to storage hygiene are important in maintaining the quality of the commodity and avoiding losses, without the use of chemicals. Perfect storage hygiene is the basic prerequisite for successful storage and for effectiveness of all on-going measures, including the use of pesticides.

All hygiene measures are relatively simple, effective and cheap; but require knowledge, attentiveness, diligence, surveillance, responsibility and thoroughness (Odeyemi, 2003). Success of storage, according to her, can be determined by: maintenance of clean surroundings; keeping the commodities cool and dry; stacking on pallet, away from building walls and keeping the store in good condition always.

Reduction in pest population can be achieved through the use of planned hygiene and stock turnovers in commodity stores. Sanitation is particularly effective when directed at empty stores before they are refilled. Dunnage must be lifted and brushed off. Storage sites must be free of debris, old bags, unwanted machinery and unused dunnage and pallets. All sweepings, spoilages and residues should be removed.

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A high standard of cleanliness should be maintained by regular brushing of wall ledges, ceilings and floors. The store should be sprayed or dusted with insecticide before restocking. All commodities should be inspected before intake for excessive moisture content and infestation. Infested commodities should be rejected or fumigated before loading into storage and infested grains must not be stocked with non-infested ones. Old stocks should be disposed off before new ones are received into storage.

THE USE OF CULTURAL MEASURES

This includes:

(i) Site Selection/Location,

(ii) Mixed-cropping and

(iii) Destruction of Harvest Residues.

(i) *Site Selection /Location:-*

In the context of Integrated Pest Management (IPM), cultural or cultivation methods are understood to mean all those methods which, as well as performing their crop farming function, also have a negative impact on the conditions of life of the pests. In the best case scenario, a measure will have a negative impact on the population density of a pest and a positive impact on the natural enemy population of the pest, without having negative effect on the output of the cultivated plant (Cochrane, 1994).

Through the choice of appropriate site for crop planting, the crop is placed in a favourable habitat which promotes its healthy growth and development and increases its resistance to pests. A crop can also be fully protected against certain pest organisms when located at sites where those pests do not occur. Therefore, as the adults of maize weevil *(S. zeamais)* are good fliers and can fly long distances to infest crops on the field, store houses should be located far away from maize fields; to prevent cross-infestations.

(ii) *Mixed-cropping:-*

Karel et al., 1982, observed that *S. zeamais* populations were significantly reduced in a maize/cowpea intercrop, compared with a monocrop.

(iii) *Destruction of Harvest Residues:-*

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Harvest residues help pests survive unfavourable climatic conditions (Cochrane, 1994). The pests can be reduced considerably by destroying or ploughing in the harvest residues. Storage of dry maize in granaries immediately after harvest gives physical protection and considerably reduces infestation.

REGULATORY OR PHYTO-SANITARY MEASURES:

This is an assemblage of regulations provided by different national governments to check, restrict or exclude the entry of certain plants or their products which are likely to carry pests or diseases into a country through importation. This is done through the adoption of quarantine measures to detect infestation and effect control before products are allowed in.

MECHANICAL CONTROL MEASURES;

The various mechanical measures that can be adopted for use in grains storage, particularly cowpea, includes:

(i) Use of natural armours (Storage in shucks) and (ii) Use of Modernized storage structures

(i) The Use of Natural Armours (Storage in Shucks):-

Caswell (1976) demonstrated that bruchid attack in conventional granaries was considerably reduced when cowpea was stored in the pods compared to threshed ones in jute bags. The pod wall and shucks served as physical and possibly toxic barriers to the bruchid larva, preventing it from gaining easy access and boring into the grains, thereby reducing population build-up.

(ii) Using Modernised Storage Structures:-

A modernized form of storage system is the crib, which guarantees good aeration and even drying of seeds during storage. The unsheathed grains can be stored in the cribs for 3-6months. Adaptation has been made by fitting rodent guards on the crib stands. One good advantage of this system is the strong natural ventilation, which enables the commodities to continue drying in storage. On the contrary however, insects, and birds may have unrestricted access to the stored commodities if adequate precautions are not taken (Odeyemi and Daramola, 2000).

PHYSICAL CONTROL MEASURES:-

Physical control of stored-product pests consists basically of modifying the environment in which insects live, so that it becomes deleterious for the survival of the target species. It involves such techniques as the manipulation of factors such as temperature and humidity as well as other factors like the amount of available oxygen, carbon dioxide or carbon monoxide. Insects and mites generally have narrow environmental limits within which they survive and breed successfully.

Any technique which can alter either the temperature or the humidity, without any detectable adverse effect on the commodity will therefore provide adequate protection.
Physical Control Measures / Storage Systems been adopted in maize grains storage, includes: (i) *Solarization,* (ii) *Storage in Fireplace or Use of High Temperature,* (iii) *The Use of Low Temperature,* (iv) *Controlled Atmosphere (Hermetic) Storage* and (v) *Use of Short-wave Radiation (Irradiation).*

(i) *Solarization (Sun-drying):-*

Drying is an important aspect in grains storage, since moisture is an important factor in grains deterioration during storage. Products must be dried to sufficiently low moisture content before storage. Weevil infested maize grains are commonly spread out in the sun in Nigeria, to ride them of insects. Weevils attack on grains would reduce due to the heat of the sun which may kill or repel them. High temperature due to direct solar radiation may kill the developing larvae in the grains (Zehrer, 1980).

(ii) *Storage in Fireplace and Use of High Temperature:-*

Insects and mites die when exposed to such temperatures because of their limited physiological capacity to thermo-regulate. Eggs, larvae, pupae and adults of *C. maculatus* are all affected by the deleterious effect of high temperatures. When commodities are dried above fire, care must be taken to prevent cracking of the grains and loss of viability. Over drying or over exposure to heat source can cause breakage of seeds, damage to seed coat, bleaching, scorching, discolouration, loss of germinative power and nutritional changes. Heat exposure of cowpeas seeds therefore should not be more than 35^{0}c. Too rapid drying of seeds with high moisture content can cause damage such as bursting or 'case-hardening,' which cause the surface of the grain to dry out rapidly, sealing moisture within the inner layers. Under drying or slow drying on the other hand, results in deterioration due to fungi and bacteria. (Odeyemi & Daramola, 2000). Dry heat treatment has been found to be an effective control against all developmental stages of *S. zeamais* (Mohammed-Dawd and Morallo-Rejesus, 2000). All eggs and adult weevils were killed following exposure to 60°C for 2 hours, or 70-80°C for 1 hour. All larvae were killed when seeds were exposed to 70-80°C for 1 hour.

(iii) *The Use of Low Temperature:-*

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Most research workers store or disinfect maize and cowpea grains which have been attacked by weevils and bruchids respectively, by deep-freezing. All stages of *C. maculatus* were killed when subjected to freezing temperatures for less than 32days; eggs being more susceptible to cold than other stages of the insects (Huis van, 1991). Nakakita et al. (1997) reported that both hatching and metamorphosis of *S. zeamais* were completely inhibited at 10°C; a small number of adult *S. zeamais* emerged at 15°C.

(iv) *Controlled Atmosphere (Hermetic) Storage:-*

The hermetic technique is an air-tight technology for grain storage that functions on the principle respiration. As the insects respire and use up oxygen that are contained in the air-tight storage device, carbon dioxide builds up. The insects will die from reduced oxygen (hypoxia), lack of oxygen (anoxia) and eventual carbon dioxide build up and poisoning (hypercarbia).

This can be practiced on almost any scale as long as the devices to be used are provided with tight fitting lids which keep out air. Sealed polythene bags can also be used for partial hermetic storage of grains. Successful hermetic storage depends on the fulfillment of a number of requirements which include storing only dry grain, making sure that the containers or structures are really airtight, filling the containers as completely as possible and keeping the container at uniform, cool temperature.

BIOLOGICAL CONTROL OR USE OF NATURAL ENEMIES (Parasitoids, Predators and Antagonists):

Biological control is understood to mean the use of living organisms to reduce certain pests. Organisms employed are the natural enemies of the pest species; or individuals of the pest species, modified, such that they destroy members of their own species (Cochrane, 1994). Many natural enemies attack bruchids and curculionids (Huis van, 1991). . The parasitoid *Theocolax elegans* has also been recorded to attack *S. zeamais* (Helbig, 1998). *Beauveria bassiana* can be an effective microbial control agent if used as a preventative treatment (Moino et al., 1998). Caswell (1976) suggested that storage of maize in shucks enable the parasitoids of *S. zeamais* to overtake the fast developing population of the curculionid, at a shorter time than shelled maize grains.

BIO-TECHNOLOGICAL CONTROL AND THE USE OF RESISTANT VARIETIES *(Varietal Control):*

Maize varieties can be grown for tolerance or resistance to *S. zeamais* attack, respectively. The choice of resistant or tolerant varieties as a preventive measure is sufficient to keep the pest

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population below the control threshold (Cochrane, 1994). According to Cochrane, resistance to pests occurs in three different forms (chemical, morphological and nutritional).

Chemical - in which the plant develops substances which attract pests (*attractants*), or repel them (*repellants*).

Morphological - in which the plant develops some morphological characteristics which favour the crop but impede the development of a pest. Such characteristics include: *the plant's leaf size, shape* and *colour; the presence or absence of secretory glands; toughness of the plant's / seed's tissue or coat, and the presence of epidermal hairs* which impair the mobility of insects.

Nutritional - which is the combination of nutrients within a plant genotype, which can, in turn, make a plant appear more or less suitable for a particular pest as a source of food or as a place to lay eggs?

Wolfson et al (1991) found that a minimum ratio of 3 parts of wood ash to 4 parts of cowpeas prevented population growth of *S. zeamais* and that a 3cm layer of ash on top of stored seeds prevented infestation.

USE OF INERT MATERIALS;

The use of inert materials such as wood ash, clay, etc, for the control of curculionids, particularly *S. zeamais* respectively, has been investigated. Ash may act as a physical barrier preventing adult beetles / weevils from locating mates or gain access to the grain. Admixture with inert dusts made from clays, diatomaceous earths (diatomite), wood ash, silicates, and sand have been traditionally used to reduce insect population (De Lima, 1987; Golob, 1997). It has been reported that storing cowpea and maize grains by admixture with dry sand reduces insect damage because the sand fills the inter-granular spaces and prevents free movement of adults for oviposition (Kranz et al., 1977). Ash has been suggested for use as a grain dessicant (Akpaetok, 1994) in which case it may dessicate insect eggs, larvae, as well as adults

THE USE OF CONVENTIONAL OR SYNTHETIC INSECTICIDES (Chemical Control):

Many conventional (synthetic) insecticides have been demonstrated to be effective against curculionids, particularly *S. zeamais*; either as dusts or fumigants (Adedire, 2001). Insecticidal dusts of malathion, chlorpyrifos methyl, femitrothion, methacrifos or pirimiphos methyl (Organo-phosphorus compounds), carbaryl (cabamate) or permethrin and deltamethrin (synthetic pyrethoids) can protect maize grains stored in bags or in air-tight containers from *S. zeamais* damage for several months (Ofuya, 2001; Adedire, 2001). The use

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of synthetic insecticides in pest management is becoming less attractive, due to high cost, increased incidence of pests resistance, high mammalian toxicity, high level of persistence in the environment, workers' safety, adulteration, leaving of poisonous residues in food after use and other health hazards (Ofuya, 2001).

THE USE OF PLANT-DERIVED BOTANICAL INSECTICIDES:

Current research efforts on stored-products development are being focused more on ecologically tolerable, readily available and cheaper control measures, with particular reference to the use of plant derived insecticides, such as plant powders, oils and extracts (Adedire, 2001). There is also an increasing awareness that plants possess chemicals which naturally protect them from pests and pathogens. The tropical region is well endowed with a wide array of these floristic species with defensive chemicals and quite a number of them have been used traditionally in protecting cowpea against beetles attack (Adedire, 2001; Longe and Ofuya, 2010).

Plant materials are sometimes mixed with legume pods or seeds and maize grains in storage, for reducing bruchid attack (Golob et al., 1999). Many of the plants used have known medicinal and pharmacological properties (Sofowora, 1982) and some have been subjected to empirical verification for effectiveness against *S. zeamais* (Longe and Ofuya, 2010).

Plant products used as protectants for stored agricultural commodities are normally obtained from leaves, roots, flowers, fruits, seeds, bark and stems of plants (Dupriez and De Leener, 1989); which can be made into various forms such as plant material formulations and admixtures, dusts, wettable powders, emulsifiable concentrate formulations, plant material fumigants, repellants and anti-feedants, as well as plant oils and extracts as attractants and synergists.

THE USE OF INTEGRATED PEST MANAGEMENT APPROACH;

This is a process by which farmers draw from a range of pest control methods to achieve the most effective, economical and sustainable combination for a particular situation (Thomas and Waage, 1996). In IPM, the emphasis is placed on self-renewing pest subjugation tactics, such as use of plant resistance and biological control. Insecticides are used only when absolutely necessary, albeit judiciously. Judicious use of insecticides includes choosing selective ones (i.e. those that are less hazardous to natural enemies of insect pests) or minimum insecticide application. Ecological backlashes or other desirable side effects are thereby preventable in properly fashioned and implemented IPM programmes.

Studies have been conducted to combine different methods for integrated control of curculionids attacking cowpeas in storage. Lale (1993) and Seek et al. (1996) have demonstrated effective protection of stored beans against curculionids attack by combining hermetic storage with activity of plant-derived insecticides. Lale and Mustapha (2000) have demonstrated the possibility of combining neem seed oil with varietal resistance for the control of cowpea storage beetle. Ofuya and Reichmuth (2002) and Ofuya (2003) have also shown that the effect of modified atmospheres can be combined with low humidity for better control of the cowpea storage beetles.

CONCLUSION

It is generally clear from the above submissions, that depredation of stored food commodities by insects, particularly *Sitophilus zeamais*, constitute a major constraint to a successful cowpea production and utilization in the tropics (Ofuya, 2003) and a major factor militating against the crops availability and also food security in Nigeria (Lale, 2001). It is imperative therefore, that greater attention should be paid to the crops during storage in order to make them available for use throughout the year. Any reduction in loss between harvest and consumption would increase the availability of food grains and ensure a successful millennium development goal on food security.

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