

A Review of Biology and Management of Lesser Grain Borer, *Rhyzopertha dominica* F. (Coleoptera: Bostrichidae) in Northern Nigerian Storage System

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ABSTRACT

Grains in Nigeria are mostly produced and stored by rural farmers at the farm/village level after harvest. The prominent storage structures existing in rural areas in Nigeria are the mud rhumbus, thatched rhumbus and underground pits. During storage, different species of insect pests were observed to cause serious damage to grains. The lesser grain borer, *Rhyzopertha dominica*, is one of the major primary pests of stored grains in many regions of the world. A summary of relevant literature on the general biology and ecology of the insect, conditions favourable for pest development and its life stages is presented in this review. The paper was also intended to review feeding habits of *R. dominica*, which includes a review of various grain and non-grain substances that have been reported as forming food and potential breeding resources for the insect. Discussion on grain losses due to *R. dominica* infestation is also given in this article. Furthermore, various methods of controlling the insect are discussed. Therefore, this paper aimed at reviewing some of the available literature on biology and various control methods of *R. dominica* as a contribution to post-harvest integrated pest management (IPM) in northern Nigerian on-farm traditional granaries.

Keywords: Grain losses, Granaries, Infestation, Management, Northern Nigeria, *Rhyzopertha dominica*.

INTRODUCTION

Fresh grains are living organisms and accordingly contain organic compounds such as carbohydrates, proteins, oils and vitamins, in addition to minerals and water (USAID, 2011). Each type of food grain possesses its own characters, and understanding these features enables us to identify and attach use and monetary value to the grain. Cereal grains are the main sources of human diets. Therefore, consumers and industrial users want to eat, grow or process grain of a certain quality, so understanding these characteristics also helps us to devise means of handling, storing and processing the grain to our best advantage (USAID, 2011).

Grain losses in cereals during storage can reach 50% of the total harvest where major part of quantitative and qualitative loss of grain is caused by insects. The loss of food grain during storage due to various insect pests is a very serious problem. Climate and storage conditions, especially in the tropic countries like Nigeria, are often highly favourable for insect growth and

development, which leads to their damages to the stored grains (Pugazhvendan et al., 2009).

According to USAID (2011), more than three-quarters of the agricultural output of African smallholder farmers is kept at village level for local use and stored using traditional methods which offer some advantages as follows:

- It stores food close to the majority consumer.
- It gives farmers easy access to their assets and facilitates sale transactions.
- It does away with transport and handling costs and eliminates losses which occur at this level.
- It serves as a source of information regarding the supply of grain on the market which informs production decisions. If the household storage is still full when farming preparations are underway, this might signal that there is still an oversupply of the type of grain on

the market. An informed farmer may reduce his acreage from the over supplied grain to another crop.

Most of losses and damages to grains stored in traditional storage structures and market stores of some parts of Nigeria are caused by various types of insect pests (Utono, 2013; Mailafiya et al., 2014; Suleiman and Rugumamu, 2017). Insect infestations in stored grains lead to decrease in grains quantity, quality and seed viability (Suleiman, 2018). Among stored grain insect pests, lesser grain borer, *Rhyzopertha dominica* F., is one of the destructive insect pests which infests many cereal grains at different pre- and post-harvest levels (Edde, 2012). *R. dominica* is a worldwide insect pest, present both in field at harvesting time and in granaries and other grain storage structures (Naseem et al., 2011). It is usually a polyphagous and cosmopolitan insect pest in tropical and subtropical areas, but it has also been found in the temperate regions of the world (Majeed et al., 2015). The insect has been reported to infest and feed on variety of stored food materials including grains of all kind especially maize, wheat, rice and sorghum (Bashir, 2002; Suleiman, 2018).

STORAGE SYSTEMS OF GRAINS IN NORTHERN NIGERIA

Storage is an interim phase during transit of agricultural product from producers to consumers. The main purpose of storage for small scale in Africa is to ensure household supply and seed for planting (Adetunji, 2007). Given that agricultural production is seasonal whereas the demands for agricultural commodities are more evenly spread throughout the year. Appropriate storage of food grains is necessary to prevent food spoilage, increasing keeping quality, and for economic reasons (Karthikeyan et al., 2009; Nukenine, 2010).

The structures used for grain storage depend on the levels of storage which are in two separate categories, first the on-farm storage of harvested produce, usually in small and relatively simple structures, and the larger regional stores of greater capacity and more permanent construction (Hill, 2003; Suleiman and Rugumamu, 2017). On farm storage involves individuals where each head of household provide storage facilities for preserving small quantities of farm product after harvest for consumptions and future sales. The regional stores include large warehouses that are usually

owned by government agencies and nongovernmental organizations (Hill, 2003; Nukenine, 2010). The difference between these two types is greatest in the tropics where smallholder storage facilities may be rather crude and not too effective, and losses due to storage pests can often be high (Hill, 2003).

The prominent storage structures existing in rural areas of northern Nigeria include the mud rhumbus, thatched rhumbus, underground pits and store rooms (Utono, 2013; Mahai et al., 2015). These traditional structures are made up of local materials such as paddy straw, bamboo poles, wooden planks, reeds, ropes and mud bricks (Adejumo and Raji, 2007; Karthikeyan et al., 2009). The major structures that are commonly used for storing grains after harvest in the rural area of northern Nigeria are described here under.

MUD RHUMBUS

Mud rhumbus are specially built structures made from a mixture of dry grass and clay. Mud and grasses as materials use for construction of mud rhombus in northern Nigeria (Mahai et al., 2015). A mud rhumbu consists of a bin resting on large stones, wood or mud pillars about 50 cm off the ground (Mada et al., 2014). The mud rhumbu is constructed in circular, spherical, cylindrical or rectangular shape with single apartment or multipurpose apartment (Nukenine, 2010). The height of mud rhumbu is usually about 1.5 m with a diameter of about 1 m is covered with thatched roof. It has a capacity of 500 to 8000 kg (Mada et al., 2014; Mahai et al., 2015). It is observed that mud rhumbu is associated with dry conditions, under which is possible to reduce the moisture content of the harvested grains to the satisfactory level simply by drying it (Nukenine, 2010). These situations improve storage condition and hence could provide protection to stored grains against insect infestations.

THATCHED RHUMBUS

Thatched rhumbus are made of woven grasses resting on irregular stones and on tree logs, the elevation of the thatched rhumbus above the ground is generally low, between 100 and 600 mm (Adejumo and Raji, 2007). These make it vulnerable to pests attack especially rodent, since they can easily reach the floor of the rhumbu. To overcome this, FAO (2011) suggested the use of supporting legs of approximately 1 m long, equipped with rats guard to raise the floor of rhumbu above the ground to protect rats and

moisture from easy access to stored grains. The wall of the thatched rhombus is made up of two layers of woven grasses, being reinforced with two or three tension rings. The roof is usually conical in shape made up of straw/thatch, tree stem, polyethene sheets, and roofs and usually of two to three layers to prevent water seepage (Adejumo and Raji, 2007). They are usually cylindrical or circular in shape with various capacities which range from 500 to 8000 kg, depending on the size of the farm produce (Chattha et al., 2014).

Unthreshed grains especially sorghum and millet are usually stored in thatched rhombus, in spite of earlier reports by Gilse (1964) that sorghum stored in traditional granaries made of plant materials were more severely damaged by stored product insects than those in mud granaries. Thatched rhombus have been used for storing sorghum and millet for long by rural farmers of northern Nigeria (Utono, 2013). If improved by placing them on the supporting legs equipped with rats guard (as mentioned earlier) and walls sealed with polyethene sheets, they could provide good protection to stored grains.

UNDERGROUND PITS

Underground storage of grains is one of the earliest practices still in use in some dry land areas (Boxall, 1998). It was earlier reported that the use of pit storage was mainly for sorghum and has been the main method of long-term grain storage from pre-neolithic times up to the early 19th century (Sterling et al., 1983; Boxall, 1998). They are usually cylindrical spherical or amphoric in shape. The walls of underground pits are lined with stones, paddy straw ropes, loose straw or other plant material. After filling, the straw is placed on the top of the sorghum before closing with a plaster of mud and cow dung mixture (Boxall et al., 2004).

Grain storage using underground pit is being withdrawn due to underground water leakage and the time consuming process of unloading which makes removal inconvenient (Suleiman and Rugumamu, 2017). But Nukenine (2010) observed they are used in areas where the water table is low so that it does not endanger the content. Conversely, underground pit is hermetic, which has the advantage of reducing insect attack on the grain, and thus, reduces grain loss (Boxall et al., 2004).

STORE ROOMS

Store rooms are small room-like structures with an average size of 4 x 5 meters (Beshir, 2011).

The size of store rooms could be as large as 20 x 20 meters (FAO, 2011). They are made of mud or fired bricks and cement with corrugated iron roofing. The capacity of store rooms depends on the size of farm produce but may be up to 15 tonnes of cereals. Such stores are often of poor structure and bad storage hygiene. Bagged grain is usually stalked up to the ceiling and against all walls, making inspection and disinfestation procedures difficult (FAO, 2007). For proper inspection, bags should not be against walls and not up to the ceiling. They should be placed on wooden pallets to avoid contact with damp from the floor which promotes mould growth and favourable conditions for insect survival.

LESSER GRAIN BORER, *RHYZOPERTHA DOMINICA* F.

External Features of *Rhyzopertha dominica*

Adults of *Rhyzopertha dominica* are elongated of 2 to 3 mm long (Rees, 2007; Mason and McDonough, 2012) and sometimes up to about 5 mm long (Robinson, 2005). The beetle has varying body colours such as reddish-brown, dark-brown or black with somewhat roughed body surface (Robinson, 2005; Rees, 2007; Mason and McDonough, 2012). The body is cylindrical in cross-section and when viewed from above the head is invisible because it bends downwards and conceals (Rees, 2007). Rees (2007) observed that the tip of abdomen of *R. dominica* is tapered and end of elytra curved gradually and backwards. The surface of the thorax and the elytra are pitted. The pits on the elytra are arranged in longitudinal punctures, giving them a striated appearance and become smaller towards the posterior of the abdomen. The antenna is short, ten-segmented, and has a terminal three-jointed loose club (Mason and McDonough, 2012). Fresh body weight ranges from 0.99 to 1.38 mg, whereas mean fresh body weight is about 1.20 mg (Edde et al., 2006).

Breeding Habitat of *Rhyzopertha dominica*

The substrates that form food and potential breeding resources for *R. dominica* include cereal and leguminous grains such as rice, wheat, sorghum, oat, pearl millet, malt barley, chickpeas, peanuts and beans (Mason and McDonough, 2012; Edde, 2012). The insects also live in dead and dried wood, and are pests of timber, stored pharmaceuticals, leather stuffing, mud plaster, packaging materials made from wood, paper and bound books. However, *R. dominica* achieves its maximum reproductive

success on dry grains (Bashir, 2002; Edde et al., 2006).

Unlike most primary stored-grain pests, *R. dominica* is not known to attack cereals in the field, but it is a strong flier and has been found infesting grain, in supposedly clean stores, within weeks or months after storage (Edde et al., 2005). Recent studies suggest that the adults are likely to fly back and forth between agricultural and non-agricultural landscapes (Edde et al., 2005; Jia et al., 2008; Mahroof et al., 2010). This rapid colonization behaviour, strong flight ability and broad polyphagy, coupled with the fact that *R. dominica* has been trapped in diverse environments, including woodlands substantial distances from grain stores, led us to suspect movement of this pest between potentially natural habitats and grain storage facilities. However, there are increasing evidences suggesting that *R. dominica* may be reproducing in non-agricultural habitats in sufficient numbers to be an important source of beetles (Wright et al., 1990; Edde et al., 2005; Edde et al., 2006; Jia et al., 2008).

Life Cycle of *Rhyzopertha dominica*

Females of *R. dominica* lay up to 200 – 500 eggs in their life time (Hill, 2003; Mason and McDonough, 2012). The eggs are deposited in clusters on grain or singly among the frass produced by the insect. The egg is opaque, whitish in colour with a waxy appearance when freshly laid, but after a little while takes on a pinkish colour (Kucerova' and Stejskal, 2008; Edde, 2012; Mason and McDonough, 2012). The egg, which is oval-shaped, is about 0.5 – 0.6 mm in length and 0.2 – 0.25mm in diameter (Kucerova' and Stejskal, 2008). Egg development takes 32 days at 18.1°C but only 5 days at 36°C (Robinson, 2005; Mason and McDonough, 2012). The relationship of temperature to the length of incubation period of *R. dominica* eggs can be summarized as follows: at 28°C and 70% RH the development from egg to first instar larva is approximately 7 days; it is 11 days at 25°C and 70% RH; it is 7 – 11 days at 29°C and 75% RH; and at 36°C and 73 – 90% RH, it is approximately 5 days (Birch and Snowball, 1953).

The larvae, which are white to cream in colour with three pairs of legs and biting mouthparts, undergo four instars (Mason and McDonough, 2012). First-stage larvae cannot bore into undamaged seeds. Second-stage larvae are capable of directed movement, but the third and successive stages are C-shaped and incapable of

movement on a flat surface (Robinson, 2005). It is further observed by Robinson (2005) that Larvae develop in whole grain and remain within the kernel through four or five instars. The larva reaches its full development in the fourth instar. The length of the mature fourth instar is approximately 3.2 mm and the head is approximately 0.41 mm in diameter (Edde, 2012). The larvae eat into cereals grains where they complete their development. Larval development on wholemeal at 70% RH requires 29 days at 28°C and 46 days at 25°C (Robinson, 2005). The larvae are internal feeders and may complete their development in the grain residue (Rees, 2007; Mason and McDonough, 2012).

Pupation usually takes place in an enlarged cell in the larval feeding tunnel or may leave grain to pupate in grain dust (Edde, 2012; Mason and McDonough, 2012). The pupae of *R. dominica* have their appendages not fixed to the body. They are inactive, and their body movement is limited to the abdominal segments. Young pupae are whitish in colour, but later, brown pigment is laid down in the eye and mouthparts. Average lengths of the body and head capsule are 3.9 and 0.6 mm, respectively (Edde, 2012). The stage lasts for 5 to 8 (Robinson, 2005; Rees, 2007).

The newly formed adults emerge from the kernel by chewing through the outer grain layer and might go without food for about 3 – 5 days after emergence. They later become voracious feeders and bore into commodity (Rees, 2007; Mason and McDonough, 2012). Adults readily fly but their flight is not well oriented, and air currents carry them (Robinson, 2005; Rees, 2007; Mason and McDonough, 2012). Adults are long-lived (Rees, 2007).

Mean longevity of adult male and female *R. dominica* fed on wheat kernels at 28°C and 65% RH is 26 and 17 weeks, respectively and about 4% of the male and 3% of female beetles lived for approximately 52 weeks (Edde et al., 2006). The most suitable combination of temperature and relative humidity was recorded $30 \pm 2^\circ\text{C}$ and $75 \pm 5\%$ respectively for the growth, development and infestation of *R. dominica* (Deshwal et al., 2018).

PEST STATUS AND DAMAGE CAUSED BY *RHYZOPERTHA DOMINICA* TO GRAINS

The lesser grain borer, *Rhyzopertha dominica* F. is a very dangerous and harmful primary pest of the stored grain (Perišić et al., 2018). It is a major pest of wheat, rice, maize and sorghum around

the world (Flinn et al., 2004; Chanbang et al., 2008). Economic importance of this pest species is pertinent, and according to its adverse effect, it comes right after the wheat weevil, *Sitophilus granarius* F. (Perišić et al., 2018). The pest spends most of its life cycle (adult and larvae) in kernel and feeds with grain endosperm (Edde, 2012). It burrows at once into the seed and feeds inside and if it does not get chance, crawls actively feeding on loose starchy materials (Deshwal et al., 2018). According to Perišić et al. (2018), this feeding habit results in physical and chemical composition changes of the grains which consequently affects rheological properties of the dough obtained from such infested grains. Both the adults and grubs cause serious damage to stored grains and stored products and adult beetles are more harmful which destroy healthy grains and reduced them to frass (Arifuzzaman et al., 2014). It is further observed by Arifuzzaman et al. (2014) that *R. dominica* destroys far more than it consumes.

Rhyzopertha dominica infestations have been reported to have reduced grains to dust (Emery et al., 2011). There are three aspect of impact of *R. dominica* infestation which are loss in the quality of stored grain, loss in the quality of stored seeds and the cost to prevent or control infestation (Cuperus et al., 1990; Sanchez-marinez et al., 1997; Perišić et al., 2018). On wheat and rice, the insect larvae consume both germ and endosperm during their development in grain and thus provide more frass than *Cryptolestes ferrugineus* and *Sitophilus granarius* (Campbell and Sinha, 1976). *R. dominica* is also capable of damaging grain, causing weight losses of up to 40% compared to 19, 14, and 10% by *S. oryzae*, *T. castaneum* and *Ephestia cautella*, respectively (Sittusuang and Imura, 1987). Perišić et al. (2018) reported 7.50% grain damage of a wheat variety within ten weeks infestation period by *R. dominica*.

Rhyzopertha dominica feeding on seed germ reduces germination rates and vigour of the grains and may be followed by secondary pests and fungi (Bashir, 2002). According to Hill (2003), *R. dominica* is one of the species that show a preference for feeding on the germinal region of seeds, and so they are responsible for a loss of quality and nutritive value in cereal grains for food, and a loss of viability. Such selective damage can be quite serious economically.

It is reported that *R. dominica* infestation on wheat, maize and sorghum grains resulted in

substantial change in the contents of calcium, phosphorus, zinc, iron, copper and manganese (Jood et al., 1992). It was also observed a reduction in the starch digestibility of maize, rice and sorghum in response to *R. dominica* infestation. Single or mixed population of *T. granarium* and *R. dominica* resulted in substantial reductions in the content of total lipids, phospholipids, galactolipids, polar and non polar lipids of wheat, maize and sorghum (Jood et al., 1996). Furthermore, *R. dominica* has also been reported to decrease vitamin contents of grain. For instance, 75% level of infestation of cereals grains cause losses of 23 to 29% thiamine, 13 to 18% riboflavin and 4 to 14% niacin (Jood et al., 1992).

MANAGEMENT OF *RHYZOPERTHA DOMINICA* INFESTING STORED GRAINS

Chemical Control

The use of chemicals (insecticides) has been found to be very effective and yields immediate results (Utono, 2013). This is why insecticides continue to be the most common methods of pests control in developing countries (Udoh et al., 2000; Kamanula et al., 2011). Fumigation is one of the chemical methods applied for pest control in buildings, ware houses, small bags, soil, seed and stored products (Upadhyay and Ahmad, 2011). Methyl bromide is one of the most effective fumigants in the control of stored pests which resulted in 100% mortality of adult and immature stages of storage insects, such as *S. oryzae*, *R. dominica* and *T. castaneum* (El-Lakwah and Abd-El-Aziz, 2000). However, it is banned from 2015 as per Montreal Protocol, due to its ozone depleting nature (Fields and White, 2002; Philips and Throne, 2010). As a result, managing storage insects has become more of a challenge.

Despite fumigants remain a popular means of controlling insect pests in the stores, their use may be limited by some problems such as the ability of steel corrugated bins to retain fumigant (Herrman, 1998).

Some organophosphate insecticides such as azamethiophos, fenitrothion, chlorpyrifos-methyl, and pirimiphos-methyl show toxic effect on Liposcelid psocid (Collins et al., 2000). Mvumi and Giga (1994) reported that effective control of *T. castaneum* and *S. zeamais* was achieved in traditional granaries using pirimiphos-methyl, with the damage level kept at < 8%. Similarly, acetic acid brine solution

impeded pupa and adult emergence and also decreases their survival (Yokoyama and Miller, 2004).

In Nigeria, magnesium phosphide, pirimiphos-methyl and permethrin are the most common insecticides used to control stored grain pests (FMANR and ODA, 1996). Chemicals such as Coopex (Permethrin 0.5%), Cypermethrin and Actellic dust are applied on stored commodity against insect pests. Golob et al. (2002) described permethrin as a synthetic pyrethroid that acts by interfering with the electrical signal passing down the axon of insect's nerve cells leading to loss of co-ordination and ultimate death.

Indiscriminate use of insecticides and lack of knowledge of the appropriate application rate by some farmers contribute to their overuse, which results in the development of resistance and detrimental effects to the environment and non-target species (Hill, 1987; Campbell and Campbell, 2001; Snelder et al., 2007; Soujanya et al., 2016). Continuous use of chemicals to control storage is likely to result in more insect resistance, health and environmental problems, which is emerging in developing countries. It is therefore necessary to make judicious use of insecticides which could be incorporated with alternative control methods and improvement of grain handling and storage systems.

Cultural Control

This method of controlling insect pests can be carried out by growing the crop far from stores to avoid easy access by flying insects such as *S. zeamais* (Abugri, 2011). It also involves general cleanliness of the storage structure such as cleaning food store houses all around, removal of dirt, egg shells and dead larvae. Furthermore, cultural control measures include removal and burning of infested broken grains before storing new grains and proper fumigation of stores in order to reduce insect pests attack (Upadhyay and Ahmad, 2011; Rugumamu, 2015).

A hygienic storage can serve as an alternative to the use of chemical insecticides. This was supported by Gwinner et al. (1996) that proper cleaning of storage areas during or before storage may reduce pest outbreaks at a cost that farmers can afford. Upadhyay and Ahmad (2011) added that all cracks and crevices in the wall, floor and ceiling of the store should be filled up, labeled and then white washed or painted by repellent paint. Incorporating good hygiene with protectants could improve the efficiency of

storage system. This was demonstrated by Arthur et al. (2006) who recovered high populations of *Sitophilus* spp. and *Cryptolestes* spp. in samples of grain residues from a commercial elevator.

Physical Control

Abugri (2011) among others describes physical methods as smoking, thermal disinfestations, use of ashes, sand and powders, to injure the insect cuticle leading to dehydration and death. The report added that termite soil caused adult mortality of *S. zeamais* in maize. In the past, grain dryers have been used to help with disinfestations, but it has been observed that insect control using high temperature may produce variable results (CGC, 2013). Throne (1994) reported the lower and upper limits for weevil's development from egg to adult stage as 15.6 and 32.5°C respectively at 75% R.H. Therefore, heating of storage areas to at least 50°C for an adequate amount of time could be effective for disinfesting invasive pests (Roesli et al., 2003). Since stored product insect pests do not feed or reproduce at temperatures below 18°C, keeping grain at -5°C for 12 weeks would control the pests at all life stages (CGC, 2013).

Cleaning during grinding operations, dry cool storage and hermetically sealed packaging can all play an effective role in conserving the seed viability with residue free pest control (Garcia-Lara et al., 2013).

Grain packaging in airtight structure is one of the most important physical methods of controlling *R. dominica*. These structures may range from well-sealed barrels holding several kilograms to 100 ton capacity metal bins. The structure should be pressure-tested to confirm air-tightness. Portable hermetic storage bags are also available (Garcia-Lara et al., 2013).

Biological Control

Bunza (2010) defined biological control as the tactic involving purposeful natural enemy manipulation to obtain a reduction in a pest status. It is the method applied to control population of pests by the use of living organisms, which can be self-sustaining, non-polluting and inexpensive. Insects, arachnids, amphibians, reptiles and mammals are the animals usually used in biological control (Bunza, 2010). Moore (1992) had earlier reported promising results when a parasitoid, *Gyranoidea* sp., was introduced against the mango mealy bug in Togo.

Upadhyay and Ahmad (2011) observed that the most commonly Hymenoptera parasitoids are used to reduce infestation and damage done by stored grain insects. *Beauveria bassiana* isolates for instance, was reported to cause 68% adult mortality of *S. zeamais* (Rondelli et al., 2012). Schöller (2010) reported the commercial availability of parasitoids of the genus *Trichogramma* that attack both moth eggs and larvae in stored products.

Although biological control is good and effective, knowledge is required on the biological control agents, how to source and use them, which may be too expensive for small-scale farmers to practice. Subsistence farmers need cheap and non-hazardous control methods in order to effectively protect their farm produce from insect pest infestations.

Botanical Insecticides

The hazardous nature of synthetic insecticides leads to search for less hazardous and environment-friendly methods such as the use of botanicals in the control of insect pests (Suleiman and Rugumamu, 2017). Botanical insecticides are naturally occurring insecticides which are driven from plants (Golob et al., 1999; Isman, 2000). Compared to synthetic compound, biopesticides are less harmful to the environment, generally less expensive and easy processed and use by farmers and small industries.

Botanical insecticides are used in several forms, such as powders, solvent extract, essential oils and whole plants, these preparations have been investigated for their insecticidal activity including their action as repellents, anti-feedants and insect growth regulators (Weaver and Subramanyam, 2000). The introduction of powdered leaves of *Salvia officinalis* L. and *Artemisia absinthium* L. to wheat grains was very effective in reducing population size and delaying development time of *R. dominica* (Klys, 2004).

Plant essential oils and solvent extracts are the most studied botanical method of controlling stored grain insect infestation (Stoll, 2000; Shaaya, et al., 2003; Moreire et al., 2007; Rozman et al., 2007). The essential oils obtained from different plant species repel several insect pests and possess ovicidal and larvicidal properties. For instance, Moreire et al. (2007) reported that *R. dominica* was more susceptible than *Sitophilus zeamais* and *Oryzaephilus*

surinamensis to hexane crude extract of *Ageratum conyzoides*. Although they are considered as environmental-friendly pesticides (Suleiman and Rugumamu, 2017), some botanicals, especially oils, are toxic to a broad range of animals, including mammals (Bakkali et al., 2008). Suthisut et al. (2011) found that some natural products were actually more dangerous to use than the commercial insecticides, because much more of the product is needed to control the insects than the fumigation or the synthetic contact insecticide.

Plant oils are also used for their fumigant activity against *R. dominica* (Lee et al., 2004) on the basis of their efficacy, economic value and used in large scale storage. In spite of the wide-spread recognition of insecticidal properties of plants, few commercial product obtained from plants are in use and botanicals used as insecticides constitute only 1% of the world insecticide market (Rozman et al., 2007).

CONCLUSION

Various on-farm storage system have been adopted by farmers of northern Nigeria to keep their farm produce. These storage structures include mud rhumbu, thatched rhumbu, underground pit and store room. It has been observed that different types of insect pests attack and cause damages to stored grains. Among the insect pests, *Rhyzopertha dominica* is one of the most difficult to manage with insecticide grain protectants in traditional storage systems due to its ability to migrate into the grain storage. The population of *R. dominica* may also build up rapidly as both sexes of the insect respond to pheromones emitted by early arriving males. Based on this literature review, it is noticeable that IPM is the best measure to suppress population growth of *R. dominica* in stored grains. This is important in order to minimize the application of chemical insecticides which are unfriendly to the environment.

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A Review of Biology and Management of Lesser Grain Borer, *Rhyzopertha dominica* F. (Coleoptera: Bostrichidae) in Northern Nigerian Storage System

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A Review of Biology and Management of Lesser Grain Borer, *Rhyzopertha dominica* F. (Coleoptera: Bostrichidae) in Northern Nigerian Storage System

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