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STORE INSECT PESTS AND MITES OF WHEAT IN SUDAN, A PRESPECTIVE REVIEW

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ABSTRACT

The store insect pests of wheat in Sudan were found to include the khabra beetle [*Trogoderma granarium* (Everts)], the flour beetle [*Tribolium castaneum* (Hrbst)], the long – headed flour beetle [*Latheticus oryzae* (Water House)], the saw – toothed grain beetle [*Oryzaephilus surinamensis* (Linnaeus)], the lesser grain borer [*Rhyzopertha dominica* (Fabricus)], the warehouse moth [*Ephestia* (*Anagasta*) *kuehnilla* (*Cautella*) Walker], the grain weevil [*Sitophilus granarius*(Linnaeus)], the Angoumois grain moth [*Sitotroga cerealella* (Olivier)], the flat – headed flour beetle (*Cryptolestes* sp.) the acarus mite (*Acarus siro* Linnaeus), and unidentified mites. All these insects and acarids were reported in some or all of the following states *viz.* Khartoum, Gezira, River Nile, Northern, White Nile, Kassala, Gadarif, Red Sea, Blue Nile, North Kordofan and South Darfur. The biology of these insects was studied in Sudan such as the life history of *T. castaneum*, *T. granarium* and *E. cautella*. However, the susceptibility studies of some Sudanese wheat cultivars revealed that Dibera variety is more resistant to *T. granarium*, *T. castaneum*, *R. dominica* and *S. oryzae* than Nilein variety. Another study followed reported Dibera as the most susceptible to *T. granarium* descended by Nilein then Vee/ PJN112 whereas condor was not attacked and found free from damage. The host range of these insects is rather broad *i.e.* almost all the mentioned pests of wheat grain attack sorghum grain and some of them attack other members of the family graminae (e.g. rice, millet, maize, etc...), leguminous crops (e. g. soybean, fababean, groundnuts, lentil, etc…), they also attack sesame, tamarind, sunflower, water melon seeds and dates. The control of these store product insects (SPI) includes a variety of methods that include proper harvest time and selection of high quality tolerant varieties as prerequisites for a hygienic wheat produce. However, some preventive measures of control include using hygienic stores, good inspection of the sacks before being stored and fumigation by methyl bromide and phosphine. However, the fumigation can be a curative treatment but should not be more than twice, to avoid residues beyond the tolerance level, and a third fumigation should be undertaken when absolutely necessary. The neem derivatives were found very potent in controlling SPI and this beside the advantage of being organic. Some studies determined the susceptibility of some SPI to other botanical insecticides that include cucurbit extracts to *T. castaneum*, garlic oil on *T. castaneum* and *R. dominica*. Other studies include the susceptibility of fenitrothion, primiphos – methyl, chlorpyrifos – methyl, deltamethrin and malathion on *T. castaneum* and *R. dominica*. However, the loss assessment due to infestation of wheat grains is a function of storage time and any infestation reduces the market value markedly. This review of the works on SPI of wheat in Sudan stimulates further studies on sound control methods (including IPM strategies), study of the biology of unstudied species and the susceptibility of the wheat varieties to SPI should be included as a prerequisite before passing them. Frequent questionnaires should be designed to pinpoint the deficiencies in the control program(s). However, the role of the government should be activated in private stores, silos and grain markets

Keywords: *STORE, WHEAT, SUDAN, PRESPECTIVE, REVIEW.*

INTRODUCTION

Wheat is the second most important cereal crop after sorghum in Sudan. Wheat consumption is increasing progressively, as a sorghum substitute, during the last decades due to a shift in the food habits. Sudan imports about 1.1 million tons of wheat grain and flour to cover demands. Wheat is grown as a winter crop in almost all the irrigated schemes in Sudan. The average acreage of wheat in Sudan was 258,000 and 92,000 ha in 1990 and 2000 seasons, respectively (Kabbashi, 2006a). The three great mills and the other 8 across the country they collectively produce 1.5 million tons / annum topped by an equal amount imported annually (Mckee, 2010)

Storage in its overall connotation covers some complex and critical functions. Firstly it provides for the physical safety of food grains for longer periods. Secondly it prevents losses and prevents the quality of the grain including its nutritional value. Thirdly storage is the king pin for a sound food security system. Thus storage management, forms an integrated part of post harvest operations, has at the hub of management of food economy of any country (Krishnamurthy, 1989). The post harvest losses of wheat grains have been estimated to about 30%. In countries like Sudan, insects cause a lot of damage to stored grains and flour where the prevailing climates create conditions favorable to insect multiplication. (Lal, 1990). A recent estimate, in Pakistan, puts the total preventable post - harvest losses of food grains at about 20 million tons a year, which is nearly 10 – 25% of the total production (Khushk and Memon, 2006). However, Kabbashi and Suliman (2006a) reported, in a survey, that insect infestation reduces sorghum prices by 10 – 50%. The stored flour, unlike grain, deteriorates rapidly with increase in time and temperature. Elshazali (personal communication) stated that the damage in flour is due to its essential pest (*Tribolium castaneum* Hrbst) which is itself considered a minor pest of intact grains since it is incapable of invading them. Yet it is responsible for rather the major losses in grains (due to grain cracking for a variety of reasons). Elnazeer (2000) prepared a comprehensive list of store insect pests in Sudan. However, this list mentioned the following pests of wheat *viz.* the khabra beetle [*Trogoderma granarium* (Everts)], the flour beetle [*Tribolium castaneum* (Hrbst)], the long – headed flour beetle [*Latheticus oryzae* (Water House)], the saw – toothed grain beetle [*Oryzaephilus surinamensis* (Linnaeus)], the lesser grain borer [*Rhyzopertha dominica* (Fabricus)], the warehouse moth [*Ephestia* (*Anagasta*) *kuehnilla* (*Cautella*) Walker], the grain weevil [*Sitophilus granaries* (Linnaeus)], the Angoumois grain moth [*Sitotroga cerealella* (Olivier)], the flat – headed flour beetle (*Cryptolestes* sp.) the acarus mite (*Acarus siro* Linnaeus), and unidentified mites. All these insects and acarids were reported in some or all of the following states *viz.* Khartoum, Gezira, River Nile, Northern, White Nile, Kassala, Gadarif, Red Sea, Blue Nile, North Kordofan and South Darfur. The biology of some of these insects was studied in Sudan such as the life history of *T. castaneum*, *T. granarium* and *E. cautella*. Darling (1951) considered *T. granarium* the most important stored grain pest under high temperature and very dry conditions. Saad (1969) reported that it was probably gained entrance on 1944 on imported wheat and established itself as a common pest of stores and warehouses in the northern and central parts of the country. Badawy and Hassan (1964) described it as the most destructive of store insects. The larva is harmful, adults being harmless. The larva feeds primarily on wheat germ and this causes great economic loss both in quantity and quality as well as reduction in the germination capacity of the damaged seeds. Mohamed (2003) reported that a lot of studies on *T. granarium* were directed to stored sorghum and work on the sorghum substitute and rival, wheat, is less approached. He did a susceptibility of four wheat varieties, grown in Sudan, to *T. granarium*. His parameters of study included, percentage loss in grain weight and percentage of damaged seeds which are clearly associated with the development of the pest. During six month storage Debeira was found the most susceptible followed by Elnilein then Vee/ PJN 112. Condor was not attacked and found completely free from damage and there was neither loss in weight nor any development of the tested insect in this variety. The germination capacity follow the same order in the tested varieties being highest in Condor and lowest in Dibeira and 100% in the control. The hardness of seeds was found negatively correlated with the susceptibility to the test insect. This study was preceded by Elnazeer's in 1998 at Wad Medani. Samples of the study were collected from Blue Nile Mills, Gezira Mills and Gezira Scheme stores and Gezira State stores. Insects encountered in these wheat samples were *T. granarium*, *T. castaneum*, *R. dominica*, *O. surinamiensis*, *S. oryzae*, *Ephestia* spp., *S. cerealella*, and unidentified mites which considered as a base line data. Her results showed 0, 0.167, 0.029, 0.049, 0.511, and1.098% monthly weevilled grains for Dibeira variety collected form Gezira scheme stores for the period May – October 1997. The corresponding results for Nilein variety were 0, 0.374, 0.274, 0.186, 2.552 and 3.203%. She concluded to a high percentage of loss in Blue Nile Mills and Gezira Mills stores 6% and 8%, respectively due to their negligent stores. The number of insects and percent loss in weight in Gezira Scheme stores and Gezira State stores was not significant due to storage hygiene and prophylactic treatments before and during storage which prevent cross infestation.

The grain merchants in Khartoum State explained the practices they follow to combat insect infestation as (1) Inspection before buying, practiced by 97% of the sampled population (PBSP) (2) Control practices (PBSP 85%) (3) Sieving (PBSP 67%) (4) Suitable storage (PBSP 70%) (5) Cooperation with Federal Plant Protection Directorate (PPD) (PBSP 11%) (6) Willingness for that cooperation (PBSP 38%) (7) No mixing with infested samples (PBSP 75%) (8) Other methods such as exposure to direct sun (33%). However, 41% of the sampled population claimed infestation affects the prices negatively, 20% claimed to affect it positively, and 39% didn't know, 93% claimed infestation affects selling whereas 49%, 43% and 8% claimed a price reduction of 10, 25, and 50%, respectively for the infested grains (Kabbashi and Suliman, 2006a).

The plant quarantine in Sudan is supervised by PPD. The procedure followed ISTA rules of seed testing "five hundred seeds taken from a sample and examined under a stereoscopic binocular microscope (25 – 40X) and a magnifying lens". The examination includes the impurities such as plant debris, sclerotia, galls, discolouration, malformation and insects (ISTA, 1996).

Krishnamurthy, (1989) described the prophylactic treatment of food grain stocks to always be coupled with godown hygiene programme. That is, sources of insect infestation should be identified and attended to appropriately. The jute bag bundles etc... should be disinfested and kept in room where no food grains are stored. Un-attended furniture etc. should be removed from the food grain godown, cracks and crevices on the flour and walls should be repaired, walls, trusses, floor and floor corners, especially, should be well swept after brushing the surface of bags in the stack. The sweeping should be sieved to salvage food grains and the sievings are burned or buried, infested food should not be brought into the godown which is free of insect infestation. The infested stocks should be fumigated in another shed called "isolation shed". He mentioned the materials used for prophylactic treatment to include (1) Inert materials [wood, cattle dung ashes, kaolinic and bentonite clays, diatomaceous earth, talk, activated clays, gypsum, katelsouse (calcium phosphate and suphate), viveanite (ferric sulphate), vegetable oil etc….. (2) Botanicals (different plant leaves e.g. neem, insecticides derived from plants like pyrethrum and derris, extracts of arrow root, etc….) (3) Synthetic organic chemicals (Malathion®, primiphos methyl, DDVP®, fenitrothion, Lindane®, pyrethroids etc…) (4) Other synthetic insecticides recommended for use in grain stores include bromophos, iodofenphos, methacrifos, phoxim, bioresmethrin, premethrin, deltamethrin etc…(5) More toxic insecticides that include Dieldrin® (Cyclodiiene), and carbamate insecticides like bendio – carb, propoxur and dioxacarb. Dieldrin® is used for the control of cockroaches and termite proofing of storage buildings. Carbamates are used to control cockroaches and ants.

The control of wheat store pests is lead by the federal PPD. The recommended insecticides include: (1) Methyl bromide® (MB) at rate of 1 pound/ m^3 for fumigation and of ships stores in particular (2) Phostoxin® at a rate 3 tabs/ to (a tab weigh 10 g and evolves 3 g phosphine), for stores and (3) a combination of Phostoxin® and carbon dioxide (at 2:1 ratio) as fumigants. The other recommended insecticides include (1) Malathion® 57% EC at a rate of 1 Litre/ 100 litre water (2) Decis® EC at a rate of 1L/ 100 L water and (3) Danitol 10% EC at a rate of 1 L/ 100 L diesel for fogging. The latter three insecticides are used for disinfestation of stores whereas Danitol is used for unpacked store wheat. The great control practices were taken in (1) Ten ports that include Port Sudan, Kassala, Gedarif, Gerri, Khartoum airport, Soba, Elobeid, Elfasher, Halfa and PPD HQ (2) The big flour mills in Khartoum which have their own insecticides under the supervision of PPD authority (3) Big stores in Khartoum and other states upon owners' requests (Suliman and Abdelsadig, personal communication).

Storage pests usually develop resistance to chemicals. Most storage pests have developed resistance to chemicals such as malathion and lindane (Ecresam, 2005). Therefore development of improved alternative technology (ies) for appropriate control of storage insect pests is needed.

Discussion

The work on the store insect pests of grains in Sudan is voluminous and exhibited a lot of report of these creatures whose conflicting interest with human life. However, more work is needed to report new pests and/ or their natural enemies and in wheat in particular which received little attention compared to sorghum. However, no report of natural enemies of insect pests in Sudan, whereas an entomological research team in Gezira Research Station practices rearing and augmentation of *Tricogramma* sp., a parasitoid of African Boll worm (*Helicoverpa armigera* Hb.), on *E. cautella* and *Cosyra cephalonica*, this parasitoid is a good food for *T. castaneum* so it is not a suitable biological agent for stored grains in Sudan. However, a lot of research executed in other countries in this field such as that of the department of animal ecology, Hohenheim University, Stuttgart, Germany (Collatz, personal communication). However, it was reported that the successful biocontrol programmes in the world reflected about 16% control of the targeted pest(s). This percentage may be very economic due to less cost of this type of control beside the high safety in its application and has no future complications to rise.

The botanical insecticides are not well exploited in control practices of insects in general and store insects in particular. However, the great rise in the demand of organic products may dictate and/ or encourage the use of these insecticides, besides being safe and environmentally friendly products. Abdelrahman (1998) proved the efficacy of a number of synthetic and garlic oil for the control of some store insects including *T. castaneum*. Siddig (2009) proved the efficacy of neem seed extracts against *T. castaneum* having different storage periods. Kabbashi and Ali (2004) recommend the control of *T. cataneum* by temperature/ time regimes 50°C for two hours and 55°C for one hour. He and others recommend 55°C and one hour for a kg packed flour to disinfest them from *T. castaneum* (Kabbashi, 2009). Inert dust and activated clays which used as prophylactic materials act by lacerating the body or by absorbing waxy substances from the insect cuticle and thus exposing the insects to dehydration and death (Krishnamurthy, 1989). The role of nanoparticles in this dehydration and toxicity needed more research and subsequent allocation. However, the toxicity of nanopackaging for insects and microbes is well known. It is worth reporting that, in Sudan ashes are used to control insects especially cockroaches but this art is limited to some rural areas and not adopted in large scale in spite of its economic and safe application. All these and other research works advocate the exploitation of botanical insecticides and innovative methods in controlling store product insects.

The use of synthetic insecticides faces a lot of limitations and the best way to avoid them is to be done by expertise. The availability and random application of these products yield some known catastrophes in Sudan and other developing countries. However, the development of resistance of store insects to insecticides is reported in tremendous research programmes including that of store insects. Dieldrin ran the same route of DDT in insect resistance and Lindane has a larger safety margin than the banned DDT (Büchel, 1983). However, the insecticides used now are either more recently recommended insecticides such as Danitol or insecticides brought by the great mills. However, in either case the used insecticides must follow the official rules for the safety purposes of all parties. Environment Protection Association (EPA) (US) has taken an action under clean air arc on methyl bromide since it significantly contributes to the destruction of the earth stratospheric ozone layer. Consequently the production and importation of this insecticide have been reduced since 1991 to the following levels (at a rate of 25% / two years) (1) 25% 1999 (2) 50% 2001 (3) 75% 2003 and (5) 100% 2005 (6) exemption is for the emergency uses. This decision is lagging in Sudan whereas in USA they are seeking the alternatives to this insecticide and they proposed a number of insect control tools to substitute that. That is because there is no alternative for all the uses of MB but a number of insect control tools can manage the pests currently controlled with MB (http:// EPA.com).

The efforts of the breeders in the production of new varieties, almost, lacking the coordination with the postharvest entomologists and scientists. However, a lot work can be done on the resistance of these products before been recommended such as the seed hardness which is related to store insect resistance and the resistance to these pests in general which may be biochemical or otherwise. Kabbashi, (2006b) did a thorough evaluation of some 13 varieties of sorghum including the reputable Tabat. That work included the seed hardness and the overall susceptibility of these varieties to *T. castaneum*. Mohamed (2003) evaluated the resistance of Dibeira and Elnilein to *T. garanarium* under laboratory conditions and reported the first to be more susceptible to that pest than the latter. However, Elnazeer (1998) reported Elnilein to be more susceptible to store weevils than Dibeira in six month study of samples from Gezira Scheme stores. The paradox in the two studies may be due to the difference in the storage conditions in Elnazeer's study since the study was a survey rather than been an adequate comparison. More research on the susceptibility of wheat varieties to store insects is needed for more economic and valuable exploitation of this strategic commodity. This may assist in cutting the loss in the production / processing/ consumption chain which already suffers big crisis such as that of the fire in Russia and torrents of Pakistan.

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