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Population dynamics of stored maize insect pests in warehouses in two districts of Ghana

N. Manu [a], E.A. Osekre [a], G.P. Opit [d], J.F. Campbell [b,*], F.H. Arthur [b], G. Mbata [c], P.R. Armstrong [b], J.K. Danso [a]

[a] Dept. of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[b] USDA, Agricultural Research Service, Center for Grain and Animal Health Research, 1515 College Ave., Manhattan, KS 66502, USA
[c] Agricultural Research Station, Fort Valley State University, 1005 State University Drive, Fort Valley, GA 31030, USA
[d] Dept. of Entomology and Plant Pathology, Oklahoma State University, 127 Noble Research Center, Stillwater, OK 74078-3033, USA

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ABSTRACT

Understanding what insect species are present and their temporal and spatial patterns of distribution is important for developing a successful integrated pest management strategy for food storage in warehouses. Maize is stored in bags in warehouses in many countries in sub-Saharan Africa, but little monitoring information is available on insect activity in those warehouses. We monitored the populations of major post-harvest insect pests of maize at three different warehouses (MiDA, Gundaa and Wienco) in two regions in Ghana (Middle Belt and Northern Belt). The study was conducted from September 2015–July 2016, which represents a common maize harvest and storage period in the two regions. The most abundant insect pest found in the warehouses was *Plodia interpunctella* (Hübner), but other major pest species were recovered during the study. *Sitotroga cerealella* (Oliver) and *Prostephanus truncatus* (Horn) which are major pests on farms, were more likely to be captured in traps outside or at nearby farms than inside the warehouses. When recovered inside they tended to be found in the receiving and cleaning areas. *Sitophilus* spp. were commonly captured in the warehouses, but were more abundant in the Middle Belt warehouse. Our results identified the major species found during warehouse storage of maize in Ghana and suggest that the specific pest species may be different in warehouses compared to on-farm storage.

1. Introduction

Maize (*Zea mays* L.) is the most extensively cultivated cereal in the world and serves as a staple in many tropical, sub-tropical and warm temperate countries, including most parts of Africa (Onwueme and Sinha, 1991; FAOSTAT, 2014). Maize, together with rice and wheat, provides at least 30% of food calories to more than 4.5 billion people in developing countries (Shiferaw et al., 2011) and it is predicted that by 2050 demand for maize in the developing world will double (Rosegrant et al., 2009). Production of maize in Africa was estimated at ~37 million ha in 2014 (FAOSTAT, 2014). Maize storage and handling conditions in developing countries are often inadequate and farmers can experience large post-harvest grain losses (Jonsson and Kashweka, 1987; Boxall, 2001; World Bank, 2011). If processes such as threshing, drying and transporting are not properly conducted after harvest, grains can have a high moisture content and kernels can become cracked or broken. This can increase infestation by insects and fungi during storage, and lead to increased losses (Hodges, 2012). Accurate estimates of post-harvest losses are difficult to obtain, but a meta-analysis of post-harvest losses indicated that mean quantity losses for maize ranged between 5.6 and 25.5% (Affognon et al., 2015).

In the West African country of Ghana, maize is an important crop, with over one million ha harvested in 2014, and a production level of more than one million metric tons (FAOSTAT, 2014). The FAO GIEWS Country Brief for Ghana (2017) stated that 1.8 million metric tons were produced in 2016, an increase of 6% over the 2015 crop year. The Ministry of Food and Agriculture (2011) in Ghana estimated 84% of maize grown in Ghana is in the middle–southern region (Brong Ahafo, Eastern, and Ashanti regions), with the remaining 16% cultivated in the Northern Belt (Northern, Upper East, and Upper West regions). Smallholder, low-resourced, farmers

* Corresponding author.
E-mail address: james.campbell@ars.usda.gov (J.F. Campbell).

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produce maize under rain-fed conditions in most of the production zones in Ghana (Cordain, 1999; Ministry of Food and Agriculture, 2011). In Ghana, there are two maize crops per year in the middle-southern region (major and minor seasons) and one crop per year in the Northern Belt. Danso et al., (2017) found that generally more insect infestations occurred during the minor season in the middle-southern region than during the major season, but that aflatoxin levels were higher in the major season. After harvest, maize can be stored at the smallholder farmer level or it can follow a chain of post-harvest operations as it moves from the field to storage in warehouses before distribution to the final consumer. Losses in quantity and quality can occur all along this chain, with Danso et al. (2017) finding insect infestations occurring in the field before harvest and when piled after harvest, but generally decreasing after the grain is dried and ready for storage. A survey by Amankwah (2009) indicated that most farmers in the Middle Belt of Ghana, a transitional zone that lies between the coastal and upland areas, use the traditional crib for dry-storage of maize after harvest, while others keep their maize in bags stored in their homes. Storage and transport of grain in sacks such as jute or polypropylene bags can be more practical and use has increased among farmers (FAO, 1994). Warehousing of bagged maize is also increasing in Ghana and this has the potential to improve the storage conditions by making it easier to inspect, treat, and distribute the grain.

There is little knowledge on insect activity at warehouses in Ghana even though this information is critical to understanding the potential for bagged maize to become infested with insects during warehouse storage. The main insect pests reported to attack stored maize in Ghana are the maize weevil, *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae) and larger grain borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) (Vowotor et al., 2005). In an evaluation of insects associated with maize from the field to post-drying stage in Ghana, Danso et al. (2017) found that *S. zeamais*, Angoumois grain moth *Sitotroga cerealella* (Oliver) (Lepidoptera: Gelechiidae), square-neck grain beetle *Cathartus quadricollis* Guerin-Meneville (Coleoptera: Silvanidae), and corn sap beetle *Carpophilus dimidiatus* Fabricius (Coleoptera: Nitidulidae) were the predominate species recovered. However, other reported insect pests that are damaging to stored maize in sub-Saharan Africa include the lesser grain borer, *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae) and Indianmeal moth *Plodia interpunctella* (Hubner) (Lepidoptera: Pyralidae) (Midega et al., 2016) are also likely to be found in Ghana. Pheromone and kairomone baited traps can be used for monitoring pest insect activity and to guide pest management programs, although pheromone trap captures are relative estimates of abundance and efficacy of capture will depend on the trap and attractants used (Campbell et al., 2002).

Evaluation of factors responsible for post-harvest losses has focused on smallholder farm level activities, but with development of food distribution channels and warehouse storage there is a need for information on how to best manage losses and maintain quality throughout the value chain (Affognon et al., 2015). The objective of this study was to determine for the first time stored-product pest insect species associated with warehouse storage of maize and their seasonal patterns of abundance in the two maize growing areas in Ghana. We used pheromone or kairomone baited traps to evaluate insect activity. The data generated will provide baseline information on pest activity in and around warehouses to help in the improvement of management programs. This is part of a broader project to determine critical points of vulnerability to insect infestation in the maize distribution chain from the field to the final consumer in Ghana.

2. Materials and methods

2.1. Study sites

This study was conducted in two agro-ecological zones in Ghana — Ejura located in the Middle Belt of Ghana, between the coastal and upland areas, and Tamale located in the Guinea Savanna zone of Northern Ghana. Three warehouses were used in this study, one in the Middle Belt (MiDA, 1000-metric ton capacity) and two in Tamale (Gundaa, capacity of 500-metric ton, and Wienco, 3750-metric ton capacity). Maize was stored in the warehouses in polypropylene bags (PP) and jute bags in MiDA warehouses, PP bags in Wienco, and jute bags in Gundaa. The study was conducted from September 2015 to July 2016. In the Northern Belt, maize harvesting and processing typically occurs in December and January, with new harvest added to warehouses starting in late December. In the Middle Belt, there is a minor and major season crop of maize, with the minor season typically harvested between December and January, a similar timeframe with the Northern Belt, and the major season crop typically harvested between late July to early September. There is a delay between harvest and storage in the warehouses, while the maize is being processed and dried. The major season crop was not the focus of this study to facilitate comparison between the two regions in Ghana.

The three warehouses all had stacking rooms, where bags of grain were stacked on pallets, but the Gundaa and Wienco warehouses had receiving and cleaning rooms as well. In the MiDA warehouse, large quantities of major season grain were stored in the warehouse at start of the monitoring period and when new grain started to be added to the warehouse at the end of the monitoring period. In the Gundaa warehouse, there was only a small amount of grain left and carried over in the warehouse until the new maize from harvest was added in January 2016. Different cereal grains (millet, sorghum, and rice), legumes, and groundnuts were stored in the Gundaa warehouse until November 2015, when all the bags were removed. In the Gundaa warehouse, grain was stored in only the receiving and cleaning rooms, not the stacking room. The Wienco warehouse was empty at the start of the study and only started receiving new grain for storage in late December 2015. Although the Wienco warehouse had receiving and cleaning rooms, only the stacking rooms were used for storage.

Data loggers (UX100 Temp/RH, Onset Computer Corp, Pocasset, MA, USA) to record temperature and r.h. were installed in each warehouse. Data loggers were attached to walls of warehouses by hanging them on nails. Average temperature and r.h. over each monitoring period was calculated. Maize moisture content was not measured as part of this study, but information from markets in the region is available. In the Middle Belt maize moisture content content ranged between 8.52 and 16.5% from October to December 2015; between 8.8 and 12.1% from January to March 2016 and between 11.2 and 12.5% from April to June 2016 (JKD, unpublished data). In the Northern Belt maize moisture content in the markets ranged between 7.8 and 15.7% from October to December 2015; between 5.5 and 9.6% from January to March 2016; and between 8.8 and 11.6% from April to June 2016 (NM, unpublished data).

2.2. Pheromone traps

Two types of traps were used for monitoring stored-product insects. Storgard II traps baited with pheromone lures (Trece Incorporated, Adair, Oklahoma, USA) were used to monitor the populations of flying insect pests inside and outside the warehouses. The pheromone lures were for *S. cerealella, R. dominica, P. truncatus*, *P. interpunctella,* and red flour beetle (*Tribolium castaneum* (Herbst)) and confused flour beetle (*Tribolium confusum*