Insect pests of post-harvest storage in promising crop sectors in Burkina Faso: current concerns and prospects for solutions

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Abstract

Effective post-harvest management of crops could significantly contribute to food security by improving the availability and quality of food. In Burkina Faso, new concerns have emerged as a result of the growing importance accorded to sesame (Sesamum indica), roselle (Hibiscus sabdariffa), "zamnè" (Acacia macrostachya), and sorghum (Sorghum bicolor). The insects identified as storage pests on these crops belong mainly to the order Coleoptera and families of Chrysomelidae, Curculionidae and Bostrichidae are the most representative. The studies carried out allowed a better knowledge of the pests as well as their economic importance. Losses due to insects, estimated up to 100% depending on the crop and protection methods used, are frequently observed after a few months of grain storage. Several alternatives to the use of chemicals including biological control, biopesticides and hermetic storage are being promoted. The triple bagging technology is one of the promising alternatives that can adapt to the post-harvest storage of a wide range of crops. Despite its proven effectiveness for several commodities, there is need to verify its efficiency against a diversity of insect pests with differing behaviour and evolution. The importance of the challenges is such that the strategies to be implemented must be conceived in a comprehensive, integrated approach, even at the regional scale.

Keywords: Post-harvest concerns, Promising crop sectors, Grain beetles, Storage alternative methods, capacity building, Burkina Faso, regional integrated strategies.

Introduction

Persistent food insecurity in sub-Saharan Africa is a complex and multifactorial phenomenon (FAO, 2017). While it is true that food insecurity is related to the inadequacy of agricultural production in general, it is also important to recognize the role of inappropriate post-harvest management practices. In 2011, post-harvest losses were estimated by FAO and the World Bank in sub-Saharan Africa at around $ 4 billion a year for an estimated total annual production of $ 27 billion (World Bank, NRI and FAO, 2011). In addition, it is estimated that lost food could meet the minimum annual needs of at least 48 million people.

In Burkina Faso, agriculture is booming with growing interest in some crop sectors. To overcome food and nutritional insufficiency and reduce poverty, it is important to support the efforts made by farmers and government policies to increase crop productivity through appropriate post-harvest management strategies. The promising sectors mainly include food crops, legumes and/or oil crops, which are increasingly considered as cash crops. For the most part, these crops are important for food security of the majority of the population in the country and are an essential element of the livelihoods of smallholders.

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the most important cereals in the semi-arid tropics providing a major source of dietary energy and protein for nearly a billion people living in semi-arid areas (Belton and Taylor, 2004; Awika and Rooney, 2004). In Burkina Faso, sorghum serves as the major staple food crop with a total annual production of 1,435,640 tons in 2015-2016 (INSD, 2016). Burkina Faso is the third largest African producer of sorghum after Nigeria and Sudan (FAOSTAT, 2016). Cowpea (*Vigna unguiculata* L. Walp.) is the most widely grown legume in Burkina Faso. All the parts of the plant are useful but the seeds, by their richness in proteins (23-30%), play an exceptional role as food. Burkina Faso is the third largest African producer with a production of 571,304 tons in 2015-2016 (FAOSTAT, 2016). "Zamnè" (*Acacia macrostachya*) is an example of a non-timber forest product of food interest in Burkina Faso. The nutritional value of seeds makes them the foods of

choice to produce nutritional improvement formulations (Hama-Ba et al., 2017). They contain nutrients that are essential for human health (Sawadogo et al., 2011). The increasing interest in this wild legume is such that «zamnè» is used in the preparation of prestigious dishes served in receptions of religious and customary ceremonies (Ganaba, 1997) where they are consumed in the form of ragout and dishes associated with cereals. (Hama-Ba et al., 2017). In economic terms, seed marketing generates substantial income for the rural population (Hagberg et al., 1996). Most of the production comes from harvests in the wild, but the importance of the plant has allowed the development of a research program to facilitate its wider domestication. Sesame (*Sesamum indicum* L) is an oilseed crop grown in several countries around the world for its seeds that are traded internationally (Amoukou et al., 2013). In Burkina Faso, sesame production has increased significantly in recent years, from 25,060 tons in 2005-2006 to more than 321,837 tons in 2014-2015 (FAOSTAT, 2016). This places Burkina Faso among the top three sesame producing countries in Africa after Sudan and Ethiopia and is the third largest agricultural export product after cotton and peanut (INSD, 2016). Unfortunately, since that date, the sector has been experiencing difficulties which are dropping production, which in 2016 was only 235,079 tons (INSD, 2016). In Burkina Faso, peanut, (*Arachis hypogeae*) is both an important food crop and a cash crop. Peanut production is becoming increasingly important with an average production increase of 9.7% compared to the five-year average, which makes a total production of 365,887 tons of unshelled peanut in 2016 (FAOSTAT, 2016). In West Africa and particularly in Burkina Faso, Roselle (*Hibiscus sabdariffa L*. Malvaceae) is receiving increasing attention as a crop with potential for making great socio-economic impacts. The Sabdariffa variety, the most important one, is grown for the production of calices, which are used in the preparation of Bissap, a high nutritional value and commercial drink (Egharevba and Law-Ogbomo, 2007; Lepengue et al., 2007; Sanou et al., 2004; Babajide, 2004).

Despite their importance, the seeds of all the above mentioned plants face post-harvest storage and management constraints, leading to variable post-harvest losses negatively impacting their availability, accessibility, and income that could result from their commercialization. In this paper, we focus on the problems, their causes, their impact and we will end up giving an overview of the solutions that are currently available or expected.

Major storage insect pests and damage caused

Post-harvest losses are correlated with economic losses since grain quality is an important determinant of market prices (Langyintuo et al., 2003). The above described crops are generally producing grains that have in common to be attacked by several species of insect pests (Tab. 1). We will describe for each of them the insects as well as the damages associated with the level of losses when possible.

Sorghum

An inventory of insects associated with sorghum storage in Burkina Faso revealed that fourteen species divided into eight families of Coleoptera and two families of Lepidoptera were recorded on the sorghum stores (Waongo et al., 2015). The most representative families included Bostrichidae, Silvanidae, Tenebrionidae, Cucujidae and Curculionidae. The Family Gelechiidae dominated the Order Lepidoptera (Waongo et al., 2015). Rhyzopertha dominica (Bostrichidae), representing 39.53% of the total number of individuals collected was the more important species responsible for the grain damage. Insects of the R. dominica species develop and feed on sorghum grains. This biological activity results mainly in a loss in weight and a production of flour from perforated and crushed grains (Waongo, 2016). After 6 months of storage in polypropylene bags, the perforated grains are estimated to 11.73% for a total grain loss of 2.87% (Lankoandé, 2017).

Cowpea

Several species of the subfamily Bruchinae (Chrysomelidae), and specifically Callosobruchus maculatus Fab., have been identified as insect pests of stored cowpeas in Burkina Faso (Ouédraogo

et al., 1996, Sanon et al., 2005). The overlapping generations of flightless form C. maculatus during cowpea post-harvest storage in West Africa are responsible of grain damage (Ouédraogo et al., 1996). Infested seeds become increasingly hollow resulting in weight loss and perforation, adult insect emergence holes at the end of larval growth. Previous studies have shown that farm storage for six months was accompanied by 70% seed infestation and about 30% weight loss and virtually unfit for consumption (Singh and Jackai, 1985).

Tab. 1. Summary information on the major insect pests and their damage in stored grains for crops under consideration, Burkina Faso.

Crops	Major insect pests	Damage caused	References
Sorghum (Sorghum bicolor L. Moench)	Rhyzopertha dominica Fabricius Oryzaephilus mercator Fauvel Cryptolestes ferrugineus Stephens Sitophilus zeamais Motschulsky Sitotroga cerealella Olivier Tribolium spp	Weight loss, crushed grain, flour	Waongo (2016) Waongo et al. (2015)
Cowpea (Vigna unguiculata L. Walp)	Callosobruchus maculatus Fab. Bruchidius atrolineatus Pic.	Weight loss, seed perforation	Sanon et al. (2005) Ouédraogo et al. (1996)
Peanut (Arahis hypogeae L.)	Caryedon serratus Olivier Tribolium castaneum Herbst Oryzaephilus surinamensis Linnaeus Plodia interpunctella Hubner	Peanut pod perforation, Aflatoxin	Ouédraogo et al. (2017)
"Zamnè" (Acacia macrostachya Reichenb. ex.De.)	Bruchidius silaceus Fahraeus Caryedon furcatus Anton & Delobel Bruchidius spp	Weight loss and seed perforation	Unpublished data
Sesame (Sesamum indicum L.)	Ephestia cautella Walker Tribolium castaneum Herbst Tribolium confusum Duval	Rancidity of seeds, mycotoxins	Sanou et al. (2011)
Roselle (Hibiscus sabdariffa L.)	Spermophagus niger Motschulsky	Seed perforation and weight loss	Koussoube et al. (2016) Sanon et al. (2017)

Peanut

Sampling of peanut stores in the farm environment identified four families of insects (Ouédraogo et al., 2017) including three families of Coleoptera, Tenebrionidae, Chrysomelidae, Silvanidae and a family of Lepidoptera (Pyralidae). Among these insects, Caryedon serratus (Chrysomelidae, Bruchinae) seems to be the predominant and the most damaging species to stored peanuts (Ouédraogo et al., 2017). Monitoring peanut stores in several localities in western Burkina Faso showed a variation in the level of infestation according to localities and a rapid increase during storage. For example, in the locality of Toussiana, the rate of perforation of the peanut pods was almost zero at the beginning of storage but this increased significantly during storage to 53.7, 81.8, 89.8 and 100% after 2, 3, 4 and 6 months of storage, respectively. Another consequence of peanut

infestation by insects is the association of insect attacks with the production of aflatoxin, which causes severe food poisoning.

The "zamnè"

Recent studies of Acacia macrostachya grain storage have identified six insect pest species belonging to three families, Chrysomelidae (Bruchinae), Tenebrionidae and Silvanidae. The last two families contain mostly secondary pests. The subfamily Bruchinae, with 3 species, represents about 98% of insects collected in stores. These are Bruchidius silaceus, Bruchidius spp. and Caryedon furcatus and responsible for the damage (Sanon, Personal observation). The main damage caused by these pests to A. macrostachya includes weight loss and seed perforation.

Sesame

From the samples of sesame seeds collected from storage, two species of Coleoptera/Tenebrionidae (*Tribolium castaneum* and *T. confusum*) and one species of Lepidoptera/Pyralidae, *Ephestia cautella* were identified as storage pests (Sanou et al., 2011). The infestation of sesame during storage by these insects causes a rancidity of the seeds rendering them unfit for human consumption. Insects also cause the loss of germinability and promote the establishment and development of mycotoxins (Sanou et al., 2011) whose consequences remain to be clarified.

Roselle

Spermophagus niger (Coleoptera: Chrysomelidae: Bruchinae) is the main pest of roselle seeds stored in Burkina Faso (Koussoubé et al., 2016, Sanon et al., 2017a). Roselle infestations by S. niger occur in the field at calyx maturity with an estimated infestation rate of 67% of the samples examined. Like other Bruchinae, development takes place in the seeds and successively passes through an egg stage, four larval stages and a pupal stage (Sanon et al., 2017a). At the beginning of grain storage, infested seeds generally had only one insect emergence hole, with seed perforation rates ranging from 1.8% to 4 % depending on their origin (Sanon et al., 2017a).

Insect control strategies during post-harvest storage

The need to protect grain during post-harvest storage is imperative to ensure the availability and quality of food commodities that are limited resources. Increasingly, crops grown for export must also meet post-harvest quality standards to compete in the international market. Although synthetic insecticides have played a key role in post-harvest grain storage, their use by farmers is nowadays criticized worldwide (Williamson et al., 2008). Furthermore, a survey of cowpea traders in Burkina Faso found that 77% of the insecticides used were neither registered nor intended for food preservation (Zongo et al., 2015). The consequences of inappropriate usages of chemicals include health and environmental risks (Idrissi et al., 2010; Zongo et al., 2015), and sometimes induce resistance in storage insect pests populations (Leontieva et al., 2006; Oyedemi et al., 2006; Opit et al., 2012). To minimize the negative effects of chemicals, many studies have investigated some components of integrated pest management with a view to developing alternatives to systematic chemical control. In Burkina Faso, studies carried out on post-harvest storage of the crop sectors considered in this paper can be grouped into three categories: biological control, botanicals, and hermetic storage.

Biological control has often been considered at the experimental level without a method of producing biological control agents and large-scale application being developed. Studies on the biological control potential of the main cowpea pest, C. maculatus, have identified the parasitoid Hymenoptera Dinarmus basalis Rond. (Pteromalidae) and Uscana lariophaga Stephan (Trichogrammatidae) as the best biocontrol agents (Sanon et al., 1998; Amevoin et al., 2007) without cost-effective methods of mass production of these biocontrol agents being available. The recent discovery of four (4) families of Parasitoids, Eulophidae, Pteromalidae, Eupelmidae and Eurytomidae associated with Bruchinae pests of A. macrostachya (Personal communication) opens interesting

perspectives of research on the possibilities of biological control of these insects. Although an important component of integrated pest management, success stories of biological control under stored food conditions are rare.

The use of botanicals is by far the most explored field of research in Burkina Faso. The data collected mainly concern cowpeas and peanuts. In Burkina Faso, since the early 2000s, several scientific investigations have focused on the control of C. maculatus using botanicals considered as promising and safe alternatives to chemicals (Sanon et al., 2017b). Extensive studies were carried out on six (6) plant species from three families including Capparaceae, Lamiaceae and Verbenanceae, through bioassays on C maculatus and cowpea storage trials. The set of data analyzed shows that several plants materials, including powders, crushed plants and essential oils (EO) were active against eggs, larvae and adults of C. maculatus, through dose-dependent mortality responses. However, EO extracted from native aromatic plants have yielded the most promising results, specifically EO from Ocimum canum (Lamiaceae) appeared as the best candidate control agent (Sanon et al., 2017). With regard to peanuts, Ouédraogo et al (2016) also tested several essential oils on eggs and adults of C. serratus. The results also showed a variable dose dependent biological activity depending on the origin of the essential oil. The current stage of research on essential oils is the conduct of toxicity tests towards humans and animals and the optimization of their use in storage conditions. For example, it is envisaged to have the essential oils carried by supports which would facilitate the treatment and improve the remanence (Ilboudo et al., 2015).

Hermetic storage is an old technique but more recently revalorized through triple bagging technology, known as PICS bags (www.ag.purdue.edu/ipia/pics). Since previous research of Sanon et al. (2011) who validated the effectiveness of a triple bag prototype in post-harvest storage of cowpeas in Burkina Faso, the effectiveness of triple bagging has been demonstrated for many commodities in Africa and around the world. Grains that are effectively preserved with triple bagging include other legumes such as bambara groundnut, peanut or pigeon pea (Baoua et al., 2014a; Sudini et al., 2015; Vales et al., 2014) cereals such as maize, rice, sorghum, wheat (Njoroge et al., 2014; Williams et al., 2017; Martin et al., 2015; Baoua et al., 2014b, 2016; Lankoandé, 2017); roselle seeds (Amadou et al., 2016). Promising crop sectors such as sesame and "«zamnè»" have been the subject of very few studies regarding post-harvest management strategies. Moreover, recently, the use of insecticides on sesame above the maximum residue limits has resulted in seizures and destruction of export grains from Burkina Faso (Personal Communication), anything that calls for greater vigilance in the production and post-harvest management of this important cash crop. In the meantime, advice is provided to producers who also have the opportunity to use or experiment with airtight containers such as PICS bags.

Prospects of future research

Post-harvest issues are a global concern. Limiting post-harvest losses throughout the food chain must be an important part of food strategies to achieve food and nutrition security. In addition, effective post-harvest management, limiting losses and improving the quality of food, can help reduce poverty through increased incomes. The diversity and the multitude of the species of insect pests of grains in the described crop sectors highlights the predominant role of this taxonomic group in the occurrence of losses in post-harvest. That is why it is crucial to find the most appropriate solutions while minimizing the use of chemicals. Concerns about crop sectors such as sesame, roselle and «zamnè» are relatively new and deserve rapid action to address them. The components of IPM already tested on other models could also be extended to these emerging sectors. In view of the proven effectiveness of triple bagging for the preservation of several grain commodities, this technology should be quickly tested and validated for the above mentioned sectors. However, the different insects identified have different ecological and biological requirements, which necessarily involve a permanent evaluation of the technology vis-à-vis the targets for efficient and sustainable post-harvest management. Any control strategy, to be effective, should be part of a comprehensive

integrated pest management approach based on the natural potential offered at national and regional levels.

References

AMADOU L., BAOUA I. B., BARIBUTSA D., WILLIAMS S. B., MURDOCH L. L., 2016. Triple bag hermetic technology for controlling a bruchid (Spermophagus sp.) (Coleoptera, Chrysomelidae) in stored Hibiscus sabdariffa grain. Journal of Stored Product Research 69, 22-25.

AMEVOIN K., A. SANON, M. APOSSABA AND I.A. GLITHO. 2007. Biological control of bruchids infesting cowpea by the introduction of Dinarmus basalis (Rondani) (Hymenoptera: Pteromalidae) adults into farmers' stores in West Africa. J. Stored Product Research, 43 (3): 240-247.

AMOUKOU, IA, BOUREIMA, S., LAWALI, S., 2013. Caractérisation agro-morphologique et étude comparative de deux méthodes d'extraction d'huile d'accessions de sésame (Sesamum indicum). Agronomie Africaine, 25 (1) : 71 – 82.

AWIKA, J.M.; ROONEY, L.W. 2004. Sorghum phytochemicals and their potential aspects on human health. Phytochemistry 65: 1199-1221.

BABAJIDE J.M. (2004) Quality and sensory evaluation of processed calyces of six varieties of Roselle (Hibiscus sabdariffa L.). Nigerian Journal Horticultural Science, 9, 110-115.

BAOUA I. B., AMADOU L., BARIBUTSA D., MURDOCH L. L., 2014a. Triple bag hermetic technology for post-harvest preservation of Bambara groundnut (Vigna subterranea (L.) Verdc.). Journal of Stored Products Research, 58(5):48-52.

BAOUA, I.B., AMADOU, L., OUSMANE, B., BARIBUTSA, D., MURDOCK, L.L. 2014b. PICS bags for postharvest storage of maize in West Africa. Journal of Stored Products Research, 58(9):20-28.

BAOUA, I.B., AMADOU, L., BAKOYE, O.N., BARIBUTSA, D., MURDOCK, L.L. 2016. Triple bagging hermetic technology for post-harvest preservation of paddy rice *Oryza sativa* in the Sahel of West Africa. Journal of Stored Products Research, 68(7):73-79.

BELTON P.S., J.R.N. TAYLOR, 2004. Sorghum and Millets: Protein Sources for Africa, Trends in Food Science and Technology, 15: 94-98.

EGHAREVBA, R.K.A., LAW-OGBOMO K.E. (2007) Comparative effects of two nitrogen sources on the growth and the yield of Roselle (*Hibiscus sabdariffa*) in rainforest region: a case study of Benin-city, Edo state. Niger. Journal of Agronomy, 6, 142-146.

FAO, 2008. Défis et opportunités pour les petites et moyennes entreprises (PME) au Burkina Faso. Forest connect, 58p

FAO. 2017. Vue d'ensemble régionale de la sécurité alimentaire et la nutrition. Le lien entre les conflits et la sécurité alimentaire et la nutrition: renforcer la résilience pour la sécurité alimentaire, la nutrition et la paix. Rapport FAO, Accra 2017. 100p.

FAOSTAT, 2016. Crop statistics. Available at: http://www.fao.org/faostat/fr/#data/QC

GANABA S., 1997. Le zamnè, un mets très apprécié. In Echo de la recherche, Eurêka n0 20 – Publication Trimestrielle du CNRST, pp 10-11.

HAGBERG S, GOMGNIMBOU M AND SOME B. 1996. Forêts classées et terres des ancêtres au Burkina Faso. Working Paper No 3: Department of Cultural Anthropology, Uppsala University, 69 p.

HAMA-BA F., SIEDOGO M., OUEDRAOGO M., DAO A., DICKO H. M. AND DIAWARA B., 2017. Modalités de consommation et valeur nutritionnelle des légumineuses alimentaires au Burkina Faso. African Journal of Food, Agriculture, Nutrition and Development, vol. 17(4): 12871-12888.

IDRISSI M., AÏT D.N., OUAMMI L., RHALEM N., SOULAYMANI A. & SOULAYMANI R.B., 2010. Intoxication aigüe par les pesticides :Données du Centre Anti Poison du Maroc (1989-2007). Toxicol Maroc, 4, 1, 5-7.

ILBOUDO Z, DABIRÉ-BINSO LCB, SANKARA F, NÉBIÉ RCH, SANON A., 2015. Optimizing the use of essential oils to protect stored cowpeas from Callosobruchus maculatus (Coleoptera: Bruchinae) damage. African Entomology, 23 (1): 94-100.

INSD, 2016. Annuaire statistique. Institut national de la statistique et de la démographie du Burkina Faso/Ministère de l'économie, des finances et du développement. 397p.

KOUSSOUBE J. C., F. MBAYE, CAKM DIA, M. SEMBÈNE, A. SANON, 2016. Genetic characterization of Spermophagus niger (Coleoptera: Chrysomelidae: Bruchinae: Amblycerini) pest associated to seeds of Sorrel (Hibiscus sabdariffa L.) in Burkina Faso. South Asian Journal of Experimental Biology 6 (1): 07-14.

LANGYINTUO A.S., LOWENBERG-DEBOER J., FAYE M., LAMBERT D., IBRO G., MOUSSA B., KERGNA A., KUSHWAHA S., MUSA S. & NTOUKAM G., 2003. Cowpea supply and demand in West and Central Africa. Field Crops Res, 82: 215-231.

LANKOANDÉ, M. (2017). Efficacité des sacs PICS (sacs à triple fond) pour la conservation du sorgho et du voandzou au Burkina Faso. Mémoire de Master, UO1-JKZ, 42p.

LEONTIEVA, T.L., BENKOVSKAYA, G.V, UDALOV, M.B., POSCRYAKOV, A.V., 2006. Insecticide resistance level in Leptinotarsa decemlineata Say population in the South Ural. Resist. Pest Mgmt. 15, 25-26.

LÉPENGUÉ A.N., M'BATCHI B., AKÉ S. (2007) Impact de Phoma sabdariffae Sacc. sur la croissance et la valeur marchande de la roselle (Hibiscus sabdariffa L. var. sabdariffa) au Gabon. Revue Ivoirienne des Sciences et Technologies, 10, 207- 216.

MARTIN D, BARIBUTSA D, HUESING JE, WILLIAMS SB, MURDOCK LL. 2015. PICS bags protect wheat grain, *Triticum aestivvum* (L.), against rice weevil, *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae). J Stored Prod Res.; 63: 22–30.

NJOROGE AW, AFFOGNON HD, MUTUNGI CM, MANONO J, LAMUKA PO, MURDOCK LL. 2014. Triple bag hermetic storage delivers a lethal punch to *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) in stored maize. J of Stored Prod Res. 58: 12–19.

ODEYEMI O.O, GBAYE O.A., AKEJU O., 2006. Resistance of callosobruchus maculatus (fab.) to pirimiphos methyl in three zones in Nigeria. 9th International Working Conference on Stored Product Protection, 325-329.

OPIT, G. P., T. W. PHILLIPS, M. J. AIKINS, and M. M. HASAN. 2012. Phosphine resistance in Tribolium castaneum and Rhyzopertha dominica from stored wheat in Oklahoma. J. Econ. Entomol. 105: 1107-1114.

OUÉDRAOGO A. P., SOU S., SANON A., MONGE J. P., HUIGNARD J., TRAN M. D. & CREDLAND P. F., 1996. Influence of temperature and humidity on populations of Callosobruchus maculatus (Coleoptera Bruchidae) and its parasitoids Dinarmus basalis (Pteromalidae) in two zones of Burkina Faso. Bull of Entomol Res, 86, 695-702.

OUÉDRAOGO I., NÉBIÉ C. R., DAKOUO D., GUENDA W., 2016. Insecticide Activity of Essential Oils on the Development of Eggs and Adult of Caryedon serratus Olivier (Coleoptera: Chrysomelidae), Pest of Stored Groundnut. Journal of Agriculture and Ecology Research International 9(2): 1-10.

OUÉDRAOGO, I., M. SEMBENE, D. DAKOUO. 2017. Inventory, Geographical distribution of Caryedon species in Burkina Faso, and evaluation of their Impact on Stored Groundnut. Advances in Entomology, 5, 55-67.

SANON A., OUÉDRAOGO A. P., TRICAULT Y., CREDLAND P. F. and HUIGNARD J. (1998) - Biological control of Bruchids in cowpea stores by release of Dinarmus basalis (Hym.: Pteromalidae) adults. Envir. Entomol. 27 (2): 717-725.

SANON A, DABIRÉ LCB, OUÉDRAOGO AP, HUIGNARD J. 2005. Field occurrence of bruchid pests of cowpea and associated parasitoids in a sub humid zone of Burkina Faso: importance on the infestation of two cowpea varieties at harvest. Plant Pathol J., 4 (1), 14-20.

SANON A, DABIRÉ-BINSO LC, BA N M, 2011. Triple-bagging of cowpeas within high density polyethylene bags to control the cowpea beetle Callosobruchus maculatus F. (Coleoptera: Bruchidae). J. Stored Product Research, 47: 210-215.

SANON A., KOUSSOUBE JC, BA MN, DABIRE-BINSO LC, SEMBÈNE M., 2017a. Report on Spermophagus niger Motschulsky, 1866 (Coleoptera: Chrysomelidae: Bruchinae: Amblycerini) infesting the seeds of roselle, Hibiscus sabdariffa L. (Malvaceae) during post-harvest storage in Burkina Faso. Journal of Stored Product Research, 72, 64-67.

SANON, A., ILBOUDO, Z., DABIRÉ L. C. B., BA, N. M., NÉBIÉ, R.C.H., 2017b. Potential of botanicals to control Callosobruchus maculatus (Col.: Chrysomelidae, Bruchinae), the main pest of stored cowpeas in Burkina Faso: Results and Prospects. Second International Conference on Pesticidal Plant. 6th - 9th February 2017, Elephant Hills Hotel, Victoria Falls, Zimbabwe.

SANOU J., OUÉDRAOGO L., SANFO D., NEYA B., SOMDA L., PARÉ P. (2004) Rapport d'activités de recherche sur le développement des fibres végétales au Burkina Faso. Campagne 2004, Farako-Bâ, CRREA-Ouest, station de Farako-Bâ. Bobo-Dioulasso, Burkina Faso. 45p.

SANOU J., ZAGRE M B., DAGANO M. J., TRAORÉ K., OUÉDRAOGO, I., COMPAORÉ E., DIASSO H. P., OUÉDRAOGO, S. 2011. Manuel de production rentable de sésame de consommation. INERA/ FNZ, 25p.

SAVADOGO A., ILBOUDO A. J. and TRAORÉ A. S., 2011. Nutritional potentials of Acacia macrostachya (Reichend) ex DC seeds of Burkina Faso: Determination of chemical composition and functional properties. Journal of Applied Sciences Research, 7 (7): 1057-1062.

SINGH, SR; JACKAI, LEN, 1985. Insect pests of cowpea in Africa; their life cycle, economic importance, and potential for control. In Singh, SR and Rachie, KO (eds.), Cowpea Research, Production, and Utilization. Chichester. John Wiley & Sons, pp 217-231.

SUDINI H., RAO G.V.R., GOWDA C.L.L., CHANDRIKA R., MARGAM V., RATHORE A., MURDOCK L.L., 2015. Purdue Improved Crop Storage (PICS) bags for safe storage of groundnuts. J. Stored Prod. Res., 64:133–138.

Vales MI, Rao GV, Ranga RH, Sudini H, Patil S. B., Murdock LL. 2014. Effective and economic storage of pigeonpea seed in triple layer plastic bags. J of Stored Prod Res. 58: 29–38.

WAONGO A., 2016. Thèse: Etude de la bioécologie de Rhyzopertha dominica f. (Coleoptera : bostrichidae) dans les stocks de sorgho (Sorghum bicolor [l.] moench) en zone nord-soudanienne du Burkina Faso : mise en place de stratégies de lutte. 92p.

WAONGO A., BA N.M., DABIRÉ-BINSO C.L., SANON A., 2015. Diversity and community structure of insect pests developing in stored sorghum in the Northern-Sudan ecological zone of Burkina Faso. Journal of Stored Product Research, 63: 6-14.

WILLIAMS SB, MURDOCK LL, BARIBUTSA D., 2017. Storage of Maize in Purdue Improved Crop Storage (PICS) Bags. PLoS ONE 12(1): e0168624.

WILLIAMSON S., BALL A. & PRETTY J., 2008. Trends in pesticide use and drivers for safer pest management in four African countries. Crop Protect, 27, 10, 1327-1334.

WORLD BANK, NRI and FAO, 2011. Missing Food: The Case of Postharvest Grain Losses in Sub-Saharan Africa. Report number 60371-AFR. 96p.

ZONGO S., ILBOUDO Z., WAONGO A., GNANKINÉ O., DOUMMA A., SEMBÈNE M., SANON A., 2015. Risques liés à l'utilisation d'insecticides au cours du stockage du niébé (vigna unguiculata l. walp.), dans la région centrale du Burkina-Faso. Rev. CAMES, serie Sciences de la Vie, de la Terre et agronomie, 3 (1) :25-31.