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Impact of Traditional Post-harvest Practices on *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) Infestation in Agro-ecological Zones of the Central African Republic

Lucie Aba-Toumnou[1,2*], Solange P. Wango[2], Emmanuel Kamba-Mebourou[1], Crépin Gbety[1], Serge F. Bolevane-Ouatinam[2] and Mbacke Sembene[3]

[1]Laboratory of Biological and Agronomical Sciences for Development, University of Bangui, BP 450 Bangui, Central African Republic.
[2]Laboratory of Applied Animal Biology and Biodiversity, University of Bangui, BP 450 Bangui, Central African Republic.
[3]Faculty of Sciences, Cheikh Anta Diop University, Dakar 5005, Senegal.

Authors' contributions

This work was carried out in collaboration between all authors. Author LAT, SPW, EKM, designed the study, performed the statistical analysis, wrote the protocol and first draft of the manuscript. Author LAT, CG and SFBO, MS managed the analyses of the study. Author SFB0, MS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Maize seeds are an important source of nutrients for human and animal. However, an important part of the seed production is lost due to the insect attacks, mainly by the weevil *S. zeamais*, a major pest of stored maize. The objective of this work was to study the impact of traditional pest management system on the development of *S. zeamais* infestation. Samples consisted of 100g of maize seeds from post-harvest. Different pest management practices (attic, polypropylene bag,

**Corresponding author: E-mail: lucieaba@gmail.com;*

sealed plastic and conservation on the cob) were considered from farmers in different localities in the three main agro-ecological zones of the Central African Republic. Samples were conserved for two months according to the different pest management practices. Damages were assessed by counting numbers of infested seeds. Results showed that after two months the sealed plastic method is the best mode of conservation (<5% of damages) in all localities. It turned out that correlations between damages and losses were higher when maize seeds are conserved in attics or by cob (r^2>0.9). In conclusion, farmers should be encouraged to use sealed plastic as the pest-management practice against *S. zeamais* infestation.

Keywords: Maize; post-harvest; Sitophilus zeamais; traditional conservation.

1. INTRODUCTION

More than 70% of the Central African Republic (CAR) population is directly involved in agriculture as the primary source of income and food security [1]. Cereal crops play a significant role in smallholder farmers' livelihoods in CAR, with maize (*Zea mays* L.), being the most important food in rural family farms. The edible seeds represent a cheap alternative source of carbohydrates, minerals and vitamins. .

Annually, significant quantitative and qualitative losses of corn due to entomological pest attacks are reported in the field, notably after harvest and during storage [2,3,4]. Insect pests generally belong to Coleopteran group (beetles) and Lepidoptera group (moths) (Getu and Abate, 1999). The maize weevil, *S. zeamais* from Coleopteran, is one of the most destructive stored product pests of grains and other processed and unprocessed stored products in sub-Saharan Africa [5,6,7,8]. *S. zeamais* causes qualitative and quantitative damage to stored products, with grain weight losses ranging between 20 to 90% for untreated stored maize [9,7,10,11] and the severity of damages depends on several factors including storage structures, physical and chemical properties of the product. Heavy infestation of adults and larvae of maize weevil which cause postharvest losses have become increasingly important constraints to storage [12,13,14,15].

One of the consequences of the high development of *S. zeamais* is the development of mycotoxins. Mycotoxins are toxic secondary metabolites secreted by microscopic fungi, which contaminate agricultural commodities before or under post-harvest conditions. They are mainly produced by *Aspergillus*, *Penicillium* and *Fusarium*. When ingested, inhaled or absorbed through the skin, mycotoxins causes lower performance, sickness or death on humans and animals. Factors that contribute to mycotoxin contamination of food in Africa include environmental, socio-economic and food production [16,17,18]. Food conservation conditions and geographical locations could play a significant role in the developmental stage of maize weevil. Maize is grown everywhere in CAR where three main agro-ecological zones can be found (Fig. 1). The objective of this work was to study the impact of traditional pest management on the development of *S. zeamais* infestation in the different agro-ecological zones of CAR.

2. MATERIALS AND METHODS

2.1 Choice of Surveyed Site

Bossangoa (6° 28' 59.999" N, 17° 26' 60" E) , Obo (5° 23′ 48″ N, 26° 29′ 33″ E), Sibut (5°43'60" N, 19°4'60" E) and Yaloke (6° 28' 59.999" N 17° 26' 60" E) were chosen to represent a range of environments and management practices in cropping systems in the main agro-ecological zones of CAR (Fig. 1). Bossangoa, Obo, Sibut and Yaloke have been considered for this study because of their high production in cereals (sorghum, corn) and legumes (groundnuts, cowpea, sesame).

2.2 Sample Collection

A questionnaire focused on the management of stored product pests in general and in particular about *S. zeamais* infestation on maize was given to the farmers. Based on the data collected from the questionnaire after two months of conservation (from October to December), the *S. zeamais* development was found to be spectacular according to the farmers. 100 g of infested maize seeds were collected in post-harvest traditional systems (Fig. 2, 3, 4 and 5) from farmers in Bossangoa, Obo, Sibut and Yaloke. Fifteen samples from each zone were collected. Fig. 2 and 3 show the traditional post-harvest practice using polypropylene bag and plastic barrel, respectively. The maize seeds after drying were put in the polypropylene bags and plastic barrels, intended to be sold or for sowing in the next agricultural season.

Fig. 4 and 5 show the traditional post-harvest practice in the field against pests. The dried maize pods are attached to the tree trunk (Fig. 4) or conserved in the attic above the fire (Fig. 5) to avoid insect attacks.

2.3 Weight loss and Damage Assessment

Damage assessment was performed by counting and weighing the number of perforated and non-perforated grains [19]. Percentages of damaged seeds were calculated as follows:

$$\%\ \text{seed damage} = \frac{\text{Number of perforated grains}}{\text{Total number of grains counted}} \times \frac{100}{1}$$

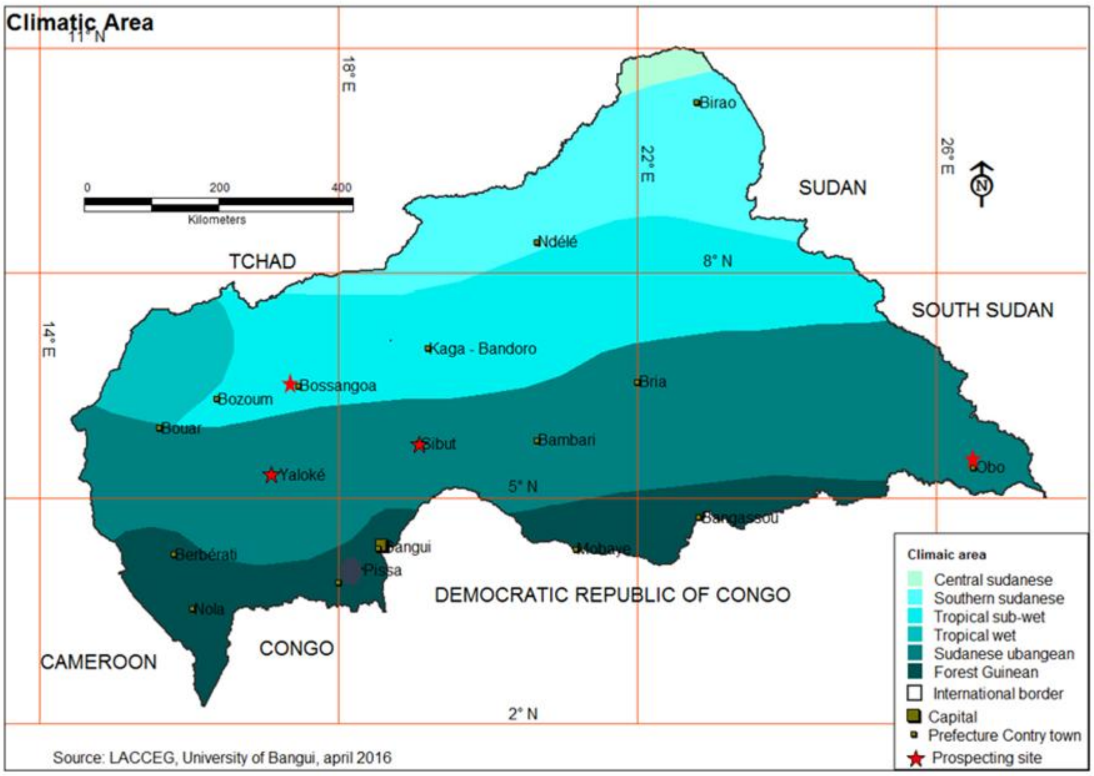

Fig. 1. Location of sites for infested seeds sampling

Fig. 2. Traditional post-harvest conservation in polypropylene bags

Fig. 3. Traditional post-harvest conservation in plastic barrels

Fig. 4. Traditional post-harvest conservation in attaching corn pods in the three

Fig. 5. Traditional post-harvest conservation in an attic with the fire under

To calculate percentages of weight loss, the method proposed by Harris and Lindblad [20] was used. This method, based on the gravimetric test, consists of counting and weighing damaged and non-damaged seeds (two replicates of 100 seeds). Data were then used to calculate percentages of weight losses according to Adams and Schulten [19] as follows:

$$\%\ \text{Weight loss} = \frac{\text{Nd x Pnd Pd x Nnd}}{(\text{Nd} + \text{Nnd})\ \text{x Pnd}}$$

Where;

Nd = Number of damaged grains,
Pnd = Weight of non-damaged grains,
Pd = Weight of damaged grains,
Nnd = Number of non-damaged grains.

2.4 Data Analysis

Analyses were performed using R software (version 3.2.3). Data about seed damages and weight losses from all surveyed zones were normally distributed (Shapiro test, $p>0.05$) and variances were homogenous (Bartlett test, $p>0.005$). To compare maize seed damages or maize seed weight losses, a Multivariate Analysis of Variances (MANOVA) was used by taking localities (Bossangoa, Obo, Sibut and Yaloke) and different storage modes (in polypropylene bags, on cobs, in attics and in sealed plastics) as explanatory variables. A One-way ANOVA was used to compare damages and weight losses between localities. Furthermore, linear models were used to assess associations between damages and weight losses.

3. RESULTS

3.1 Efficacy of Traditional Modes of Conservation

Different traditional modes of *Zea mays* conservation were explored. Fig. 6 shows that in all localities (Bossangoa, Obo, Sibut and Yaloke), plastics ARE the best mode of conservation with damage rates less than 5% after two months of conservation. This percentage is significantly lower compared to that observed in the case of conservation on cobs and in attics ($p<0.001$). However, conservation in bags gave good results in Bossangoa, Obo and Sibut (<10% of damages) after two months of conservation. Moreover, in the locality of Yaloke, conservations in bags, attics and on cobs gave damage rates between 10 and 20 % (Fig. 6), which are statistically high compared to that from the conservation in sealed plastics (1.32±0.45%, $p<0.001$) after two months of conservation.

3.2 Effects of Damages

Assessing correlations between damages caused by *S.zeamais* on maize seeds showed that globally, damages are correlated to losses (r^2 = 0.93; Fig. 7). Exploring data in each locality gave more precisions on the strength of correlations between seed damages and corresponding weight losses for each mode of conservation. Indeed, in Bossangoa, Obo and Sibut, losses were strongly correlated to the damages ($p<0.0001$) according to the traditional conservations on cobs and in attics (Table 1). By contrast, in the locality of Yaloke, damage rates recorded on cobs and in attics were two times less than recorded in the others localities. It should be noted that in Yaloke, damages were not correlated to the losses ($0.43<r^2<0.46$; Table 1). Moreover, in the plastic, very few damages were recorded (1.32±0.45%) in the locality of Yaloke.

4. DISCUSSION

Four different traditional practices used in CAR for storage of corn were compared. The results demonstrated that sealed plastic barrels are effective in controlling maize weevils in all

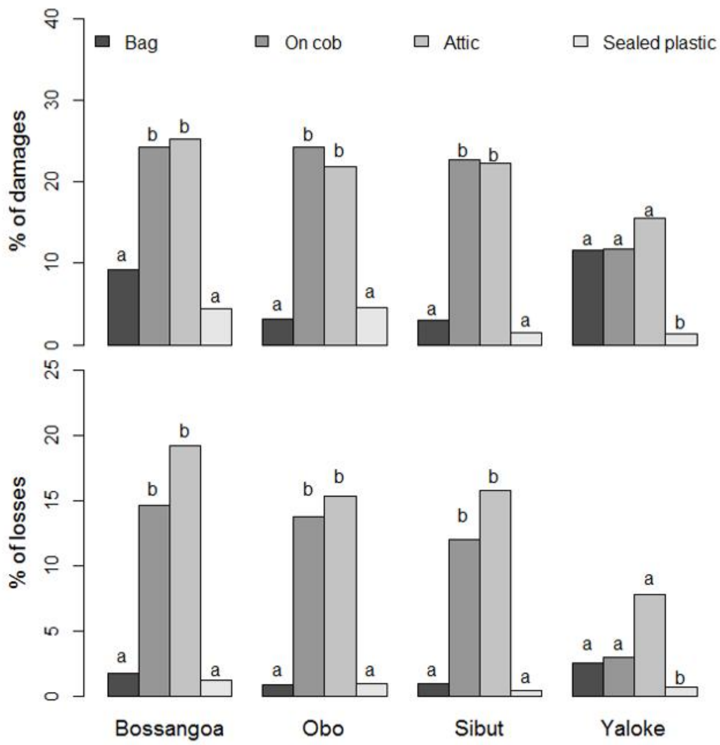

Fig. 6. Percentages of damages and losses induced by *S. zeamais* in *Zea mays* in each locality according to different conditions of storage. Bars plots with different letters above are significantly different (MANOVA, p<0.001) in each locality.

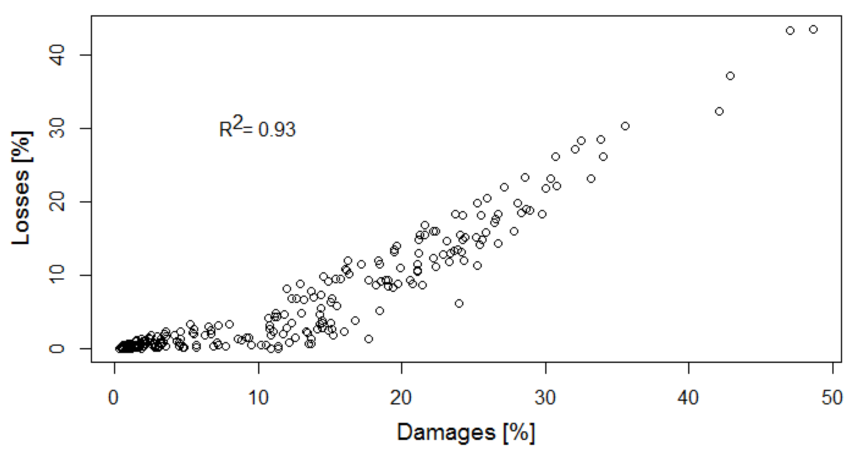

Fig. 7. Evolution of rate of losses as a function of rate of damages caused by *S.zeamais* in stored maize seeds. R^2 was calculated using the Pearson method

Table 1. Correlation between damages and losses according to storage conditions in different localities of the study

Locality	Storage conditions	Mean ± SE of damages (%)	Mean ± SE of losses (%)	Linear model	
				Correlation[a]	p-value[b]
Bossangoa	Bag	9.17±0.26	1.74±0.08	0.126	0.199
	Ear	24.32±0.52	14.68±0.54	0.985	<0.0001
	Attic	25.33±0.47	19.19±0.51	0.976	<0.0001
	Plastic	4.39±0.22	1.21±0.08	0.25	0.044
Obo	Bag	3.15±0.16	0.86±0.05	0.14	0.18
	Ear	24.25±0.25	13.77±0.3	0.92	<0.0001
	Attic	21.92±0.62	15.36±0.66	0.969	<0.0001
	Plastic	4.55±0.28	0.96±0.07	0.44	0.0064
Sibut	Bag	2.97±0.07	0.92±0.061	0.6	0.0066
	Ear	22.75±0.35	11.99±0.35	0.9	<0.0001
	Attic	22.25±0.64	15.71±0.7	0.985	<0.0001
	Plastic	1.48±0.07	0.41±0.033	0.31	0.0294
Yaloke	Bag	11.58±0.4	2.53±0.16	0.43	0.0076
	Ear	11.77±0.3	2.96±0.22	0.46	0.0051
	Attic	15.53±0.26	7.8±0.29	0.54	0.0015
	Plastic	1.32±0.45	0.68±0.04	0.6	0.00068

(a) Correlations were assessed using the Pearson method; (b) a p-value < 0.0001 means that there is a strong correlation between damages and losses. SE = Standard errors of the mean (N = 15).

localities where studies were conducted (Bossangoa, Obo, Sibut and Yaloke), with damage rates caused by *S. zeamais* were inferior to 5% after two months of conservation.

The surprising effectiveness of sealed plastic for preserving grain against insect pests is certainly due to the depletion of oxygen and the parallel rise in carbon dioxide in containers [9,21,22,8, 23]. In *S. zeamais*, low oxygen (hypoxia) leads to the cessation of larval feeding activity, whereas elevated levels of carbon dioxide (hypercarbia) have little or no effect on feeding. Cessation of feeding affects the growth of the insects, which do not mature and reproduce. As a result, population growth ceases, and damaging infestations do not develop. *S. zeamais* eggs, larvae, and pupae subjected to hypoxia eventually die after exposures to various durations [24,11]. The cause of death is desiccation resulting from an inadequate supply of water. The results show that blocking the supply of oxygen limits humidity in the containers. This leads to inactivity, cessation of population growth, desiccation and eventual death in insects [25,26].

The polypropylene bag allows air to circulate well, which is in favour of the insect pests. Thus, insect mortality was not complete, and all bags in the trial were perforated, certainly by *S. zeamais*. As appreciated many years ago, the most practical method of reducing pre-harvest attack is by preventing insect development in harvested grain [27,28,29]. Insect pests need food, air and water to live. The best place for an insect to live and grow is in stored grains because sufficient availablility of food, air and water [30,31].

Maize seed samples were collected after two months of conservation, from October to December, corresponding to the beginning of the dry season in the CAR. Surveyed localities were chosen because of their high production of cereals. Three of these localities (Sibut, Yaloke and Obo) belong to the Sudanese ubangean climatic area, whereas the Bossangoa locality belongs to the tropical wet climatic area. The results have underlined differences in damage severities caused by the development of *S. zeamais* in maize seeds. Indeed, higher damages (ca. 25%) were recorded in Bossangoa (tropical wet), similar to those recorded in the localities of Obo and Sibut (sudanese ubangean) when maize seeds were conserved on cobs or in attics. By contrast, in Yaloke (sudanese ubangean), these damages were at least two times lower. This observation indicates that the climatic region does not influence the infestation of maize seeds by *S. zeamais.* However, differences in damages observed in Yaloke and in the others surveyed localities can be explained by the fact that the population in Yaloke usually make fire close to the harvested products and suggests that cultural habits may play a role in the management of insect pests in rural zones.

5. CONCLUSION

Post-harvest losses in Africa are often estimated to be between 20 and 40% [7]. Such losses are the combination of those that occur in fields, during storage and during other marketing activities. Sealed plastics limit the development of S. *zeamais*. This is technically easy to implement for an efficient protection of stored products against the insects without using insecticides.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Conaway JL, Ouedraogo AK, Coneff J. Activité de zonage: Plus de moyensd' existence de la République Centr Africaine. USAID (United States Agency International Development), Bangui, Centrafrique. 2012;41.
2. Delobel MT. Foodstuff beetles stored in hot regions. ORSTOM, Paris. 1993;424.
3. Penning de Vries, FWT. Food security? We are losing ground fast. In Noesberger J, Geiger HH, Struik PC (Eds.), Crop Science: Progress and Prospects. 2001;1-14.
4. Muhammad S. Extermination of insect pests (Coleoptera: Bruchidae) and damage of stored pulses by different methods in market. AM J Mark Res. 2015;1(3):99-105.
5. Nukenine EN, Monglo B, Awason L, Ngamo LST, Tchuenguem FFN, Ngassoum MB. Farmer's perception on some aspects of maize production, and infestation levels of stored maize by *Sitophilus zeamais* in the Ngaoundere region of Cameroon, Cam. J. Biol. Biochem. Sci. 2002;12(1):18–30.
6. Danho M, Gaspar C, Haubruge E. The impact of grain quantity on the biology of *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae): Oviposition, distribution of eggs, adult emergence, body weight and sex ratio. Journal of Stored Products Research. 2002;38(3): 259–266.
7. World Bank, FAO, NRI. Missing food: The case of post-harvest grain losses in sub-Saharan Africa. In: Economic Sector Work Report No. 60371-AFR. World Bank, Washington, DC; 2011.
8. Narayana KC, Swamy GP, Mutthuraju E, Jagadeesh E, Thirumalaraju GT. Biology of *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) on stored maize grains. Current Biotica. 2014;8(1):76–81.
9. Sisman C. Quality losses in temporary sunflower stores and influences of storage conditions on quality losses during storage. J. Cent. Eur. Agric. 2005;6:143-15.
10. Abass AB, Ndunguru G, Mamiro P, Alenkhe B, Mlingi N, Bekunda M. Post-harvest food losses in a maize-based farming system of semi-arid savannah area of Tanzania. Journal of Stored Products Research. 2014;57:49-57.
11. Affognon H, Mutungi C, Sanginga P, Borgemeister C. Unpacking postharvest losses in Sub-Saharan Africa: A meta-analysis. World Development. 2015;66:49–68.
12. Compton JAF, Floyd S, Magrath PA, Addo, S, Gbedevis R, Agbo B, Kumi S. Involving grain traders in determining the effect of post-harvest insect damage on the price of maize in African markets. Crop Protection. 1998;17:483–489.
13. Rosenzweig C, Iglesias A, Yang XB, Epstein PR, Chivian E. Climate change and extreme weather events; implications for food production, plant diseases, and pests. Global Change & Human Health. 2001;2(2):90-104.
14. Hodges RJ, Buzby JC, Bennett B. Postharvest losses andwaste in developed and less developed countries: Opportunities toimprove resource use. Journal of Agricultural Science. 2011; 149(S1):37–45.
15. Flood J, Day R. Managing risks from pests in global commodity networks–policy perspectives. Food Security. 2016;8(1):89-101.
16. Diener UL, Cole RJ, Sanders TH, Payne A, Lee LS, Klich MA. Epidemiology of aflatoxin formation by *Aspergillus flavus*. Annual Review of Phytopathology. 1987; 25:249–270.
17. Hell K, Cardwell KF, Setamou M, Peohling HM. The influence of storage practices on aflatoxin contamination in maize in four agro-ecological zones of Benin, West Africa. J. Stored Prod. Res. 2000;36:365-382.
18. Wagacha JM, Muthomi JW. Mycotoxin problem in Africa: Current status, implications to food safety and health and possible management strategies.

International Journal of Food Microbiology. 2008;124:1-12.
19. Adams JM, Schulten GM. Loss caused by insects, mites and micro-organims. In: Harris KL, Lindblad C.J. (Eds), post-Harvest Grain Loss Assessment Methods. American Association of Cereal Chemists, USA. 1978;83-95.
20. Harris KL, Lindblad CJ. Postharvest grain loss assessment methods. Minnesota, America Association of Cereal Chemist. 1978;193.
21. Baoual B, Amadou L, Margam V, Murdock LL. Comparative evaluation of six storage methods for postharvest preservation of cowpea grain. Journal of Stored Products Research. 2012;49:171-175.
22. De Groote H, Kimenju SC, Likhayo P, Kanampiu F, Tefera T, Hellin J. Effectiveness of hermetic systems in controlling maize storage pests in Kenya. Journal of Stored Products Research. 2013;53:27-36.
23. Williams SB, Murdock LL, Baributsa D. Safe storage of maize in alternative hermetic containers. Journal of Stored Products Research. 2017;71:125-129.
24. Trematerra P, Valente A, Athanassiou CG, Kavallieratos G. Kernel-kernel interactions and behavioural responses of the adult maize weevil *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae). Appl. Entomol. Zool. 2007;42(1):129-135.
25. Murdock LL, Margam V, Baoual Balfe S, Shade RE. Death by desiccation: Effects of hermetic storage on cowpea bruchids. Journal of Stored Products Research. 2012;49:166-170.
26. Getu E, Abate T. Management of maize stem borer using sowing date at Arsi-Negele. Pest Management Journal of Ethiopia. 1999;3(1&2):47-51.
27. Zehrer W. Traditional methods of insect pest control in stored grain. In post-harvest problems. Documentation of OAU/GTZ Seminar. Schriffenreihe. 1980;115:98-129.
28. Giga DP, Mutemerewa S, Moyo G, Neeley D. Assessment and control of losses caused by insect pests in small farmers' stores in Zimbabwe. Crop Protection. 1991;10(4):287–292.
29. Addo S, Birkinshaw LA, Hodges RJ. Ten years after the arrival in Ghana oflarger grain borer: farmers' responses and adoption of IPM strategies. Int. J. Pest Manag. 2002;48:315-325.
30. Abtew A, Niassy S, Affognon H, Subramanian S, Kreiter S, Martin T. Farmers' knowledge and perception of grain, legume, pests and their management in the Eastern province of Kenya. Crop protection. 2016;87:90-97.
31. Ladang YD, Ngamo LTS, Ngassoum MB, Mapongmestsem PM, Hance T. Effect of sorghum cultivars on population growth and grain damages by the rice weevil, *Sitophilus oryzae* L. (Coleoptera: Curculionidae). African J. of Agricultural Research. 2008;3(2):255-258.

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