Impact of Traditional post-harvest practices on *Sitophilus zeamais* infestation in agro-ecological zones of the Central African Republic

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 insect attacks, mainly by the weevil *Sitophilus zeamais*, a major pest of stored maize. The objective of this work was to study the impact of traditional pest management on the development of *S. zeamais* infestation. Samples consisted of 100g of maize seeds from post-harvest. Different pest management practices (attic, polypropylene bag, 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 different pest management practices. Damages were assessed by counting numbers of infested seeds. Results showed that sealed plastic is the best mode of conservation (<5% of damages) in all localities after two months. 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.

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 (Conaway *et al*., 2012). Cereal crops play a major 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 (Delobel, 1993; Penning de Vries, 2001; Muhammad, 2015). The maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae), is one of the most destructive stored product pests of grains and other processed and unprocessed stored products in sub-Saharan Africa (Nukenine *et al*., 2002; Danho*et al*., 2002; World Bank, 2011; Narayana *et al*., 2014). *S. zeamais* causes qualitative and quantitative damage to stored products, with grain weight losses ranging between 20 to 90% for untreated stored maize (Sisman, 2005; World Bank, 2011; Abass*et al*., 2014; Affognon *et al*., 2015), and the severity of damages depends on factors which include 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 (Compton *et al.,* 1998; Rosenzweig *et al.,* 2001; Hodges *et al.,* 2011; Flood and Day, 2016) and food security in the tropics.

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 fungi of the genus *Aspergillus*, *Penicillium* and *Fusarium*. When ingested, inhaled or absorbed through the skin, mycotoxins will cause 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 (Diener *et al*., 1987; Hell *et al*., 2000; Wagacha and Muthomi, 2008). 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 (Figure 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 (figure1). 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 …).

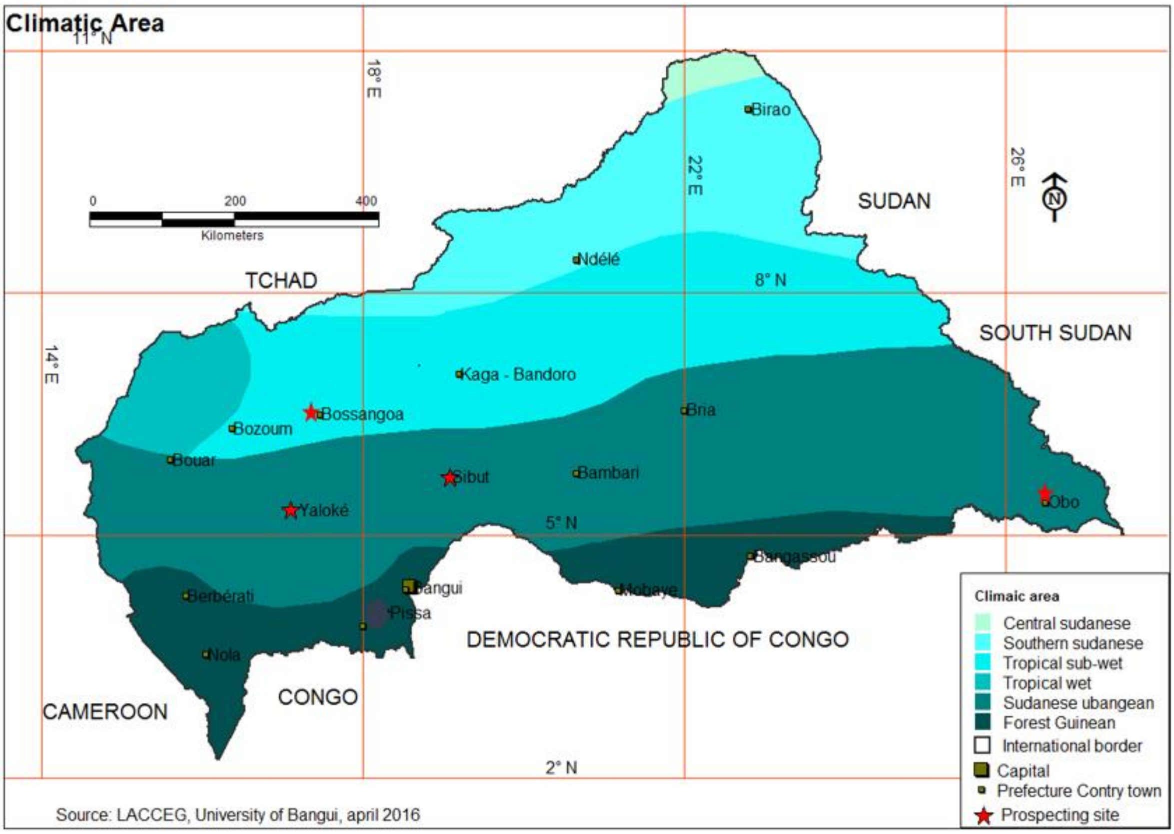

Fig. 1 Location of sites for infested seeds sampling

2.2. Sample Collection

A questionnaire focused on the management of stored product pests in general and about *S. zeamais* infestation on maize in particular was given to farmers. Basing on the data collected from the questionnaire after two months of conservation (from October to December), the *S. zeamais* development was found spectacular according to the farmers. 100g of infested seeds of maize were collected in post-harvest traditional systems (Figures 2, 3, 4 and 5) from farmers in Bossangoa, Obo, Sibut and Yaloke. 15 samples from each zone were collected. The Figure 2 and 3 show the traditional post-harvest practice using polypropylene bag and plastic barrel, respectively. The maize seeds after drying were put in polypropylene bags and plastic barrels, intended to be sold or for sowing the next agricultural season.

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

	
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 a attic with fire under

2.3. Weight loss and damage assessment

Damage assessment was performed by counting and weighing the number of perforated and non-perforated grains (Adams and Schulten, 1978). Percentages of damaged seeds were calculated as follows:

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

To calculate percentages of weight loss, the method proposed by Harris and Lindblad (1978) was used. This method, based on 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 (1978) as follows:

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

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 are normally distributed (Shapiro test, P>0.05) and variances are 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. The figure 6 shows that in all localities where studies were conducted (Bossangoa, Obo, Sibut and Yaloke), plastics are the best mode of conservation with damages 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 % (Figure 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.

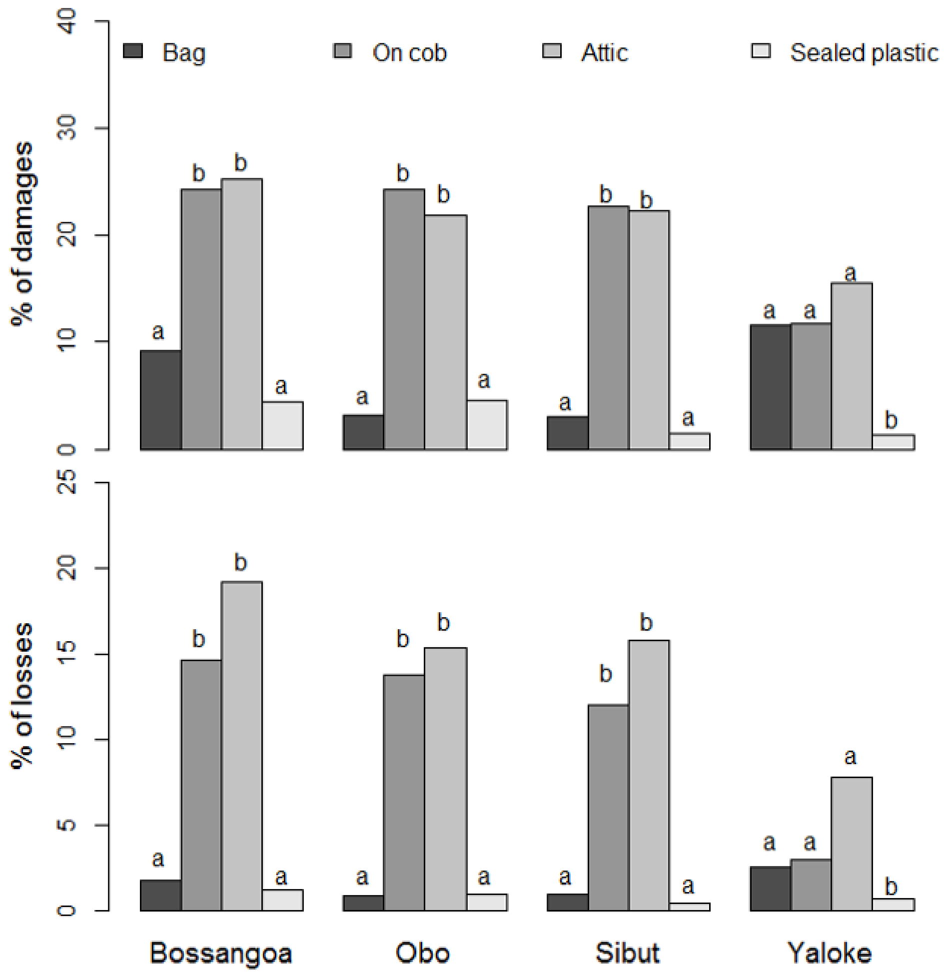

Fig. 6 Percentages of damages and losses induced by S. *zeamais* in *zea mays* in each locality according to different conditions of storage. Bars plots with different letters above are significantly different (MANOVA, P<0.001) in each locality.

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; Figure 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, damages rates recorded on cobs and in attics were two times less that 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.

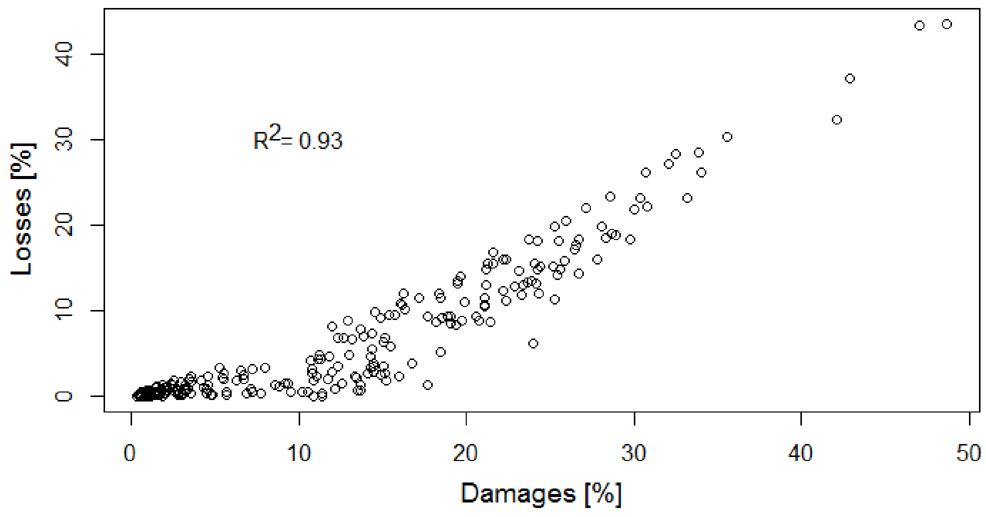

Fig. 7 Correlation between maize seed damages caused by *S. zeamais* and corresponding maize seed weight losses. R^2 was calculated using the Pearson method.

Tab. 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).

4. Discussion

Four different traditional practices used in CAR for storage of corn were compared. The results demonstrated that seal plastic barrels are effective in controlling maize weevils all localities where studies were conducted (Bossangoa, Obo, Sibut and Yaloke), with damages 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 (Sisman, 2005; Baoua *et al*., 2012; De Groote *et al*., 2013; Narayana *et al*., 2016; Scott*et al*., 2017). In *S. zeamais*, low oxygen (hypoxia) leads to 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 (Trematerra *et al*., 2007; Affognon *et al*., 2015). The cause of death is desiccation resulting from an inadequate supply of water. Our 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 (Murdoc *et al*., 2012).

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 was appreciated many years ago, the most practical method of reducing pre-harvest attack is by preventing insect development in harvested grain (Zehrer, 1980; Giga et *al*., 1991; Addo et *al*., 2002). Insect pests need food, air and water to live. The best place for insect to live and grow is in stored grains because food, air and water are sufficiently available (Abtew*et al*., 2016).

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. Our results have underlined differences in damage severities caused by the development of *S. zeamais* in maize seeds in localities surveyed. 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 climatic region do 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 harvested products and suggests that cultural habits may play a role in the management of insect pests in rural zones.

Conclusion

Post-harvest losses in Africa are often estimated to be between 20 and 40% (World Bank *et al.*, 2011). 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.

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