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# Economic Losses from Insect Pest Infestation on Rice Stored on-farm in Benin

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**Abstract:** In Benin, on-farm storage of paddy rice is increasingly exposed to pest damage. Insect infestation causes a loss of income to farmers and other post-harvest stakeholders. The objective of this study is to assess the magnitude of damage caused to rice stored on-farm and evaluate the potential economic risk. In this study, 65 stocks of paddy rice were inspected and sampled in order to assess the economic losses. In addition, an agronomic survey was carried out to determine producer perceptions about the economic impact of stored rice pests in a farming environment. The findings show that weight loss amounts to 5.47% after 6 months of storage in the southern region, 4.07% in the central region and 1.64% in the northern region. From an economic perspective, 6 months duration of storage is likely to cause an estimated loss of 21,315 FCFA (Franc of the African Financial Community) per ton of paddy in the South region, compared to losses of 8,088 FCFA in the North. Furthermore, 36.92% of farmer respondents consider that these insects cause considerable economic damage to stored rice. This study made it possible not only to assess current losses attributable to insect pests in the country but also to obtain future projections about trends in high-risk regions. These findings will undoubtedly pave the way for future research in improved stored rice protection and income safeguards for various stakeholders intervening in the post-harvest sector.

**Key words:** Economic losses, paddy rice, storage pests, rice weevil, geographical regions

## INTRODUCTION

In West Africa, rice is a highly strategic cereal due to its importance as food for the households and for domestic economy. In Benin, following on good rice production levels recorded after improved, high-yield, short cycle varieties were introduced and adopted, grain storage has gradually become an ingrained habit for the population. Therefore, the past decade has seen increasing amounts of rice stored to meet the population's subsistence needs, as well as for marketing and use as seed. As a result, although for a long time in Benin not very much was known about storage damage caused by insect pests, it began to pose a serious threat to reserves stored by producers, processors and traders. Nowadays, insect pest infestation has been observed in many on-farm paddy or hulled rice storage units. Sightings have been recorded of the rice weevil *Sitophilus oryzae* Linnaeus (Coleoptera: Curculionidae), the maize weevil *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) and the lesser grain borer *Rhyzopertha dominica* Fabricius (Coleoptera: Bostrichidae) on producer stocks in the country. Similarly, Togola *et al.* (2010) recorded infestations by the Angoumois grain moth *Sitotroga cerealella* Olivier (Lepidoptera: Gelechiidae) in many rice-producing zones in the country, causing an estimated 3-18% damage to grain, depending on the area and length of storage. As a general rule, *S. cerealella*, *S. oryzae*, *S. zeamais*, *R. dominica* and *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) are the primary insect pest species that make up the core of the parasitical complex that has a major economic impact on grain stocks worldwide (Grenier *et al.*, 1994; Hansen *et al.*, 2004). They are cosmopolitan pests (Cotton, 1960; CABI, 2005; Bamaiyi *et al.*, 2007; Plague *et al.*, 2010; Arthur *et al.*, 2012), able to attack many types of cereal grain (Sedaghat *et al.*, 2011; Hamed and Sajid, 2012). Their dispersal over large areas has come not just from changes to population feeding habits caused by drought-making farmers abandon their dryland crops to grow rice and maize (Meikle *et al.*, 1998; Hansen *et al.*, 2004) but also from uncontrolled cross border movements of grain produce fostered by regional or international trade (Youm *et al.*, 2011).

As in many African countries, studies in Benin focused on drawing up an inventory of the entomofauna of stored grain (Ngamo and Hance, 2007; Gueye *et al.*, 2011) but, as far as rice is concerned, very little research has focused on loss assessments, in general and even less on economic loss, in particular. Rice production and storage is growing rapidly and has become almost unavoidable for smallholders in the sector. It is therefore,

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necessary to carry out a study on post-harvest loss evaluation on rice taking into consideration stock predators, in general, with particular attention to insects. This is all the more essential since any grain attacked by an insect suffers not just losses in nutritional quality but also becomes unfit for marketing and for use as seed.

Prior to any pest control operation, it is useful to assess the extent of quantitative and economic losses that have occurred or are likely to affect the crop during storage in order to better appreciate the need, the time and the place for an intervention against target predators. This article aims to make such an assessment, taking into account weight and economic loss incurred as result of insect infestation on paddy rice stored on-farm in Benin. The study will permit an assessment of the extent of loss in the southern, central and northern regions of the country in order to seek solutions for improved stored rice protection and to safeguard incomes for the various actors in the post-harvest sector.

## MATERIALS AND METHODS

**Site selection and sample collection:** During 2011 and 2012 agricultural seasons, a series of entomological prospections were carried out throughout the territory of Benin. During these prospections, 65 farmer stocks were inspected and samples taken from 28 of the prospected sites. Site selection was primarily in major rice production zones from the South to the North of the country, including the Center. Temperatures, relative humidity as well as the geographic coordinates of the storage units were recorded.

**Sampling methodology:** In each site, 2 to 3 storage units were inspected, taking care to avoid treated stock. Village-based resource persons (village head, village guide or president of the rice growers association) helped to identify the producers involved. For each farmer's stock, where quantities ranged from some ten kilos to several dozen tons of paddy, a series of random samples were taken using the sampling technique recommended by the world food program (Walker and Farrell, 2003) in order to obtain an initial representative sample. For bagged rice (the most frequently encountered mode of storage on the visited sites), a representative number of bags were randomly sampled. As for bulk or grain in bins, or in earthenware pots (a minority of the producers using this method), all or part of the stock was sampled using the technique referred to above. Finally, for rice stored in sheaves (the least frequently encountered method), a representative sample of sheaves were collected.

In each of the samples, the data was stratified until a sample of one kilogram (1 kg) of paddy was retained for future investigations. Figure 1 describes the sampling technique applied.

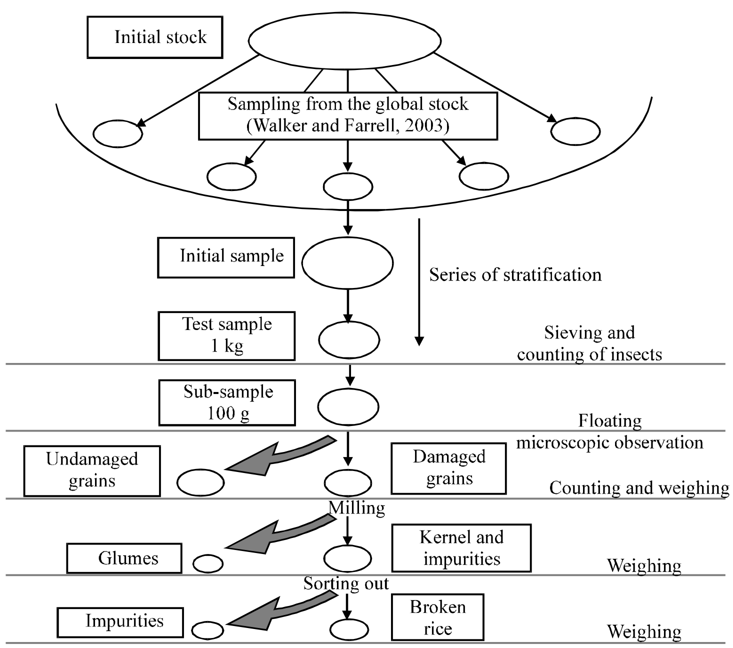


Fig. 1: Collection and sample analysis procedure, Broken rice: Damaged grains by insects

**Sample analysis methodology:** For each farmer's sample, a subset of 100 g was measured and the infested grain was floated away from the healthy grain. The different grain batches were dried for 25 min in an oven set at 40°C. Finally, the healthy grain batch was separated again under the microscope to detect the presence of any remaining infested grain, especially any with insects inside the grain. After sorting, the different grain batches were counted and weighed and glumes of the infested grains were removed by hand to extract the broken grains. Only infested grains by insects were investigated because several factors can contribute to damage and break the grains. These grains were then separated out from impurities and weighed to know their respective proportions in each sample. This analysis technique is described in Fig. 1. The weight of the impurities were not taken into account in this study as they hardly amounted to much.

**Loss evaluation methodology**

**Quantitative losses:** This is the weight loss incurred by the different stocks in the farming environment. The average percentage of infestation (A%) was assessed as a function of the number of infested grain and the volume of healthy grains based on the formula below (Harris and Lindblad, 1978):

$$A\,(\%) = \frac{Nd}{Nu+Nd} \times 100$$

Where:
Nd = No. of damaged grains
Nu = No. of undamaged grains

As for weight loss (B%), this was calculated by dividing the percentage of infestation (A%) by a conversion factor C, according to the formula:

$$B\,(\%) = \frac{A\%}{C}$$

Conversion tables are used to determine the C factor per grain type. For rice, C is equal to 2 (Harris and Lindblad, 1978). As reported by the authors, this conversion method is suitable for an estimation of on-farm storage insect pest damage. It is practical, fast and provides fairly accurate estimates.

Mention should be made of the fact that some qualitative losses from insect pests attack were not analyzed in this study and therefore, were not used for economic loss calculations. For example, loss of grain germination capacity, loss of organoleptic quality and loss in color that could be contributory factors to a loss in product marketing value. Research in the future will take them into consideration.

**Economic losses:** Total economic loss attributable to insect pests was calculated on the basis of the monetary value of the weight loss, on the one hand and price depreciation for broken rice (discount), on the other hand. The first type of loss was calculated by multiplying the price of paddy for each period by the corresponding weight loss incurred. This is the economic loss to paddy rice producers and sellers.

The second type of loss was calculated by subtracting the price (value) of broken rice due to insects from the price of whole grain. This is the additional economic loss that comes after hulling. The prices entered into the different calculations were based on producer prices set when the samples were bought or those declared by producers during the agronomy surveys. Thus, one kilogram of paddy was supplied at 150 FCFA (Franc of the African Financial Community) after 2-3 months of storage, at 200 F after 4 months and at 250 F after 5-6 months. As for the broken rice, it was sold at 210, 280 and 350 F per kilo after storage periods of 2, 3, 4 and 5-6 months, respectively. Finally, whole grain costs 300, 400 and 500 F, respectively over the same duration. Producer prices were slightly above market price because the producers saw us as project officers.

**Complementary agronomy survey:** During the prospection, complementary information was collected from local stakeholders to assess storage states (i.e., treated or not with chemicals), rice variety, total quantity and destination of the stock, initial date of storage and finally, product price and fluctuations over time. Producer perceptions about insect pest damage to stored grain were also recorded.

**Statistical data analysis:** Means of the different losses were first calculated using samples from the various farmer storage units. They were then converted into tons per farmer stock in order to ensure that all measurements were harmonized and make it easier to compare the means.

A Variance Analysis (ANOVA) was then carried out on the mean percentages of infestation, weight and economic losses using statistical analysis software (SAS, 9.1). The Student Newman Keuls test was used to separate means according to different storage periods and/or regions where samples were collected.

## RESULTS

Results showed that rice is usually stored in rural Benin for more or less long periods. From 65 storage units visited, observations were made for some 160 tons of paddy rice. Stored rice is customarily destined for trade (153,400 kg), consumption (4,950 kg) or for use as seed (2,550 kg) (Table 1). In terms of volume, nearly all of the stored paddy stock was destined for sale: 95.34% of total amounts inspected. The other stocks- especially for consumption or seed-were in the minority, both in terms of quantity and volume (Table 1).

On the basis of climate measurements taken at the different sites visited, certain regional variations were observed. Temperatures dropped slightly in the southern regions (30.4 °C) and in the center (31.2 °C), compared to the northern region where they were relatively high (32.3°C). Conversely, the relative humidity gradient regressed from 85.2 to 58.4% from the south to the north (Fig. 2).

**Quantitative loss from storage insect pests:** There were considerable variations in stored rice losses depending on study sites, geographical regions in the country and storage duration. In the southern and central regions, they were higher than in the North. In the South, infested grain percentage ranged from 3.29 to 10.94% between 2 and 6 months of storage (Fig. 3). This caused weight loss varying from 1.64 to 5.47% (Table 2). In the Center, there was just as much damage but slightly lower than in the South. Recorded percentages of infestation went from 1.8 to 8.13% between 2 and 6 months of storage (Fig. 3). As for weight losses, they ranged from 0.9 to 4.07% over the same periods (Table 2). Finally, in the North, very little damage was recorded irrespective of storage duration namely, 1.32-3.27% between 2 and 6 months of storage for infestation percentages (Fig. 3) and 0.66-1.64% for weight losses over the same periods (Table 2).

Thus, in the South and Center regions, weight loss recorded from 4 and 6 months of storage was significantly more important than that recorded for durations of less than 4 months. In the North, on the other hand, no significant variations were associated with storage duration (Table 2).

**Economic losses from storage insect pests:** As it was the case for quantitative losses, levels of economic loss varied according to geographical regions in the country and product storage periods.

For producers who sell paddy rice, economic losses were limited to weight loss values in amounts ranging from 2,471 FCFA (Franc of the African Financial Community) to 13,675 FCFA $t^{-1}$ of rice stored

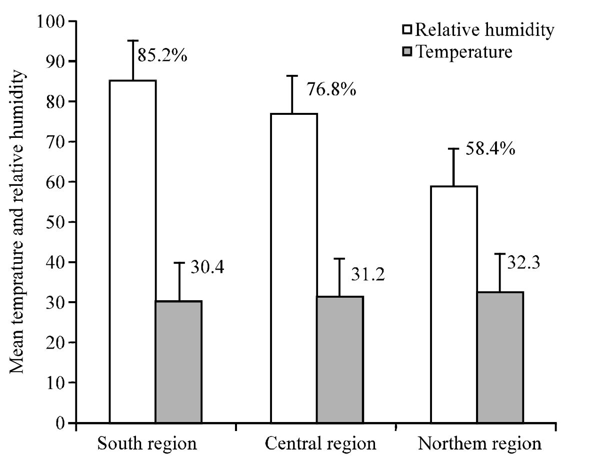


Fig. 2: Mean relative humidity and temperatures recorded during the 2011 and 2012 seasons

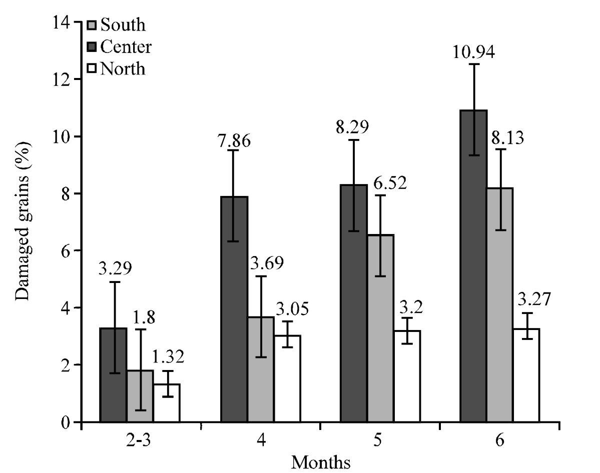


Fig. 3: Variation in insect caused damage of farm stored paddy in rural Benin

Table 1: Distribution of farmer stocks according to use and source

| | South | | Center | | North | | Total | |
|---|---|---|---|---|---|---|---|---|
| | No. of stores | Volume (kg) | No. of stores | Volume (kg) | No. of stores | Volume (kg) | No. of stores | Volume (kg) |
| Consumption | 8 | 2000 | 6 | 1800 | 4 | 1150 | 18 | 4950 |
| Seeds | 6 | 1300 | 5 | 770 | 4 | 480 | 15 | 2550 |
| Trade | 6 | 37100 | 13 | 45700 | 13 | 70600 | 32 | 153400 |
| Total | 20 | 40400 | 24 | 48270 | 21 | 72230 | 65 | 160900 |

between 2 and 6 months in the South region. Cost estimates are put at 1,350 FCFA and 10,169 FCFA for the central region and 990 FCFA and 4,096 FCFA in the North.

Of note is the fact that the economic incidence of these losses was felt more severely as from the fourth month in the South and from the fifth month in the central region. On the other hand, in the North, the incidence was insignificant irrespective of storage duration (Table 3).

Based on the total losses summing up the weight loss values and the depreciation in broken rice post-hulling prices, producers in the southern region lost, on average, between 4,197 F and 21,315 FCFA per ton of rice stored rom 2-6 months. As for the central region, overall losses amounted to 2,628 and 14 170 FCFA over the same periods. These figures dropped to 1,832 and 8,088 FCFA in the northern region. The results show a highly significant difference ($p<0.01$) between losses recorded over the different periods in the southern region. In the central region, economic losses were significant after 5 and 6 months of storage, compared to the other periods. Yet, in this region, there were no significant differences in losses recorded from 2- 3 months and those at 4 months. Finally, in the northern region, no significant variation in economic loss was related to different storage periods (Table 3).

These results showed that the economic incidence of insect damage on stored rice is only perceived as significant in the south and center of the country. In both regions, a regression analysis of the economic loss of paddy and total economic loss showed rising and linear trends depending on storage duration, with regression coefficients $R^2$ = 0,9796 for the first parameter and $R^2$ = 0,986 for the second (Fig. 4).

Table 2: Losses from insect infestation in stored paddy grains in Benin

| Storage duration (month) | Weight loss (%) South | Center | North |
|---|---|---|---|
| 2-3 | 1.64$^{b}$ | 0.09$^{b}$ | 0.66$^{a}$ |
| 4 | 3.93$^{a}$ | 1.85$^{ab}$ | 1.53$^{a}$ |
| 5 | 4.14$^{a}$ | 3.26$^{ab}$ | 2.06$^{a}$ |
| 6 | 5.47$^{a}$ | 4.07$^{a}$ | 1.64$^{a}$ |

Values followed by the same letter in the column do not differ significantly according to SNK test ($p<0.05$)

Table 3: Estimated economic losses due to insect damage to stored paddy grains in Benin

| | South | | Center | | North | |
|---|---|---|---|---|---|---|
| Storage duration (month) | Losses on paddy rice | Global losses | Losses on paddy rice | Global losses | Losses on paddy rice | Global losses |
| 2-3 | 2471$^{c}$ | 4197$^{d}$ | 1350$^{c}$ | 2628$^{b}$ | 990$^{a}$ | 1832$^{a}$ |
| 4 | 7869$^{b}$ | 10853$^{c}$ | 3705$^{bc}$ | 6264$^{ab}$ | 3060$^{a}$ | 5712$^{a}$ |
| 5 | 10367$^{ab}$ | 16212$^{b}$ | 8150$^{ab}$ | 11860$^{a}$ | 4006$^{a}$ | 7580$^{a}$ |
| 6 | 13675$^{a}$ | 21315$^{a}$ | 10169$^{a}$ | 14170$^{a}$ | 4096$^{a}$ | 8088$^{a}$ |

Values in the same column not followed by the same letter are significantly different according to SNK test ($p<0.05$)

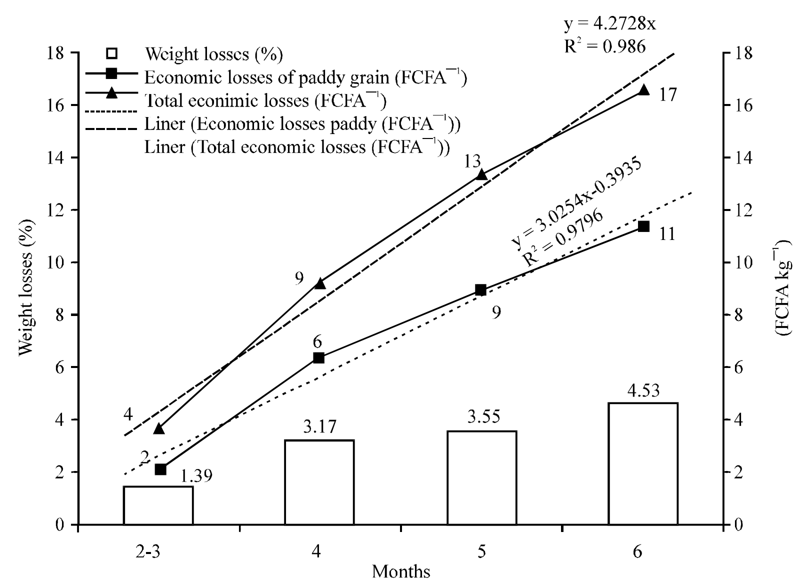


Fig. 4: Loss trends during rice storage in the southern and central regions of Benin

Table 4: Farmer perception of insect pest damage on stored rice in Benin

| | | Perception (No.) | | | |
|---|---|---|---|---|---|
| Region | No. of farmers | Insects | Rodents | i+r | No response |
| South | 20 | 4 | 8 | 6 | 2 |
| Center | 24 | 3 | 13 | 5 | 3 |
| North | 21 | 1 | 15 | 5 | 0 |
| Total | 65 | 8 | 36 | 16 | 5 |

**Farmer perception of pest infestation and storage damage:** According to the survey findings, 36.92% of the farmers considered insects as pests with a major economic impact on rice during the post-harvest period but only 12% of them ranked them at the top. In fact, more than half the farmers surveyed found that rodents (especially mice) were of greater economic impact (Table 4).

Mention should be made of the fact that the insect pests identified on stored rice were primary insect pest species, namely rice weevil (*S. oryzae*), the Angoumois grain moth (*S. cerealella*) and the lesser grain borer (*R. dominica*). They caused most of the recorded damage to farmer storage units. Rice weevil and Angoumois grain moth featured predominantly in the South and Center regions whilst the lesser grain borer was found in all three regions, although in greater numbers in the North. Of all storage insect pests, producers only vaguely recognized Coleoptera.

## DISCUSSION

Results show that paddy rice stored for long time on-farm in Benin is, to a large extent, destined for sale and to a lesser extent, for consumption and seed. In fact, producers and traders prefer to store rice destined for sale until off-season when they can sell at higher prices. This may be because Benin rice growers depend on an attractive market-at the local level as well as in Nigeria- for their paddy rice (Bauer *et al*., 2011). However, these rice distribution results may depend on sampling periods to the extent that each of the quantities in storage would depend on time of use. For example, contrary to stocks for sale, reserves for consumption are drawn on almost every day after harvesting. In some cases, they are hulled before storage as polished grains. When these factors are added to low levels of local production compared to household consumption needs, they may explain why such low quantities were recorded as stocks for consumption. Finally, it should be stated that a large quantity of stocks for sale are purchased locally or diverted to meet subsistence needs. This often makes it difficult to distinguish between stocks for sale and grain for consumption. As for seed, producers store small quantities for use during the next cropping season. In some cases, farmers only have seed during the sowing period or if they have bought some from the agricultural services that are the only large storage holders of such seed.

The scale of insect pest damage to the different farmer storage units was correlated with storage duration and regions where samples were collected. Concerning storage duration, infestation caused more damage to paddy stored between 4- 6 months than stocks less than 4 months, especially in the southern and central regions of the country. In fact, long storage periods and especially when the reserves are not treated, give the insects enough time to colonize the stocks and multiply extensively, causing considerable damage. The scale of damage caused by post-harvest insect pests correlated to storage duration was studied by Tefera *et al*. (2011). As for the effect of geographical regions on the amount of damage, it may be linked to the ecology of the insect pests. Thus, in the South and the Center of the country where temperatures are constantly low, relative humidity levels high and exposure to sunlight much less, climate conditions are particularly favourable for the reproduction and multiplication of most principal orders of insect species such as *S. cerealella* (Hansen *et al*., 2004; Perez-Mendoza *et al*., 2004; Togola *et al*., 2010) and *S. oryzae* for which favourable temperature ranges are from 15 to 32.5°C and relative humidity is between 50 and 90% (Logstaff and Evans, 1983). Similarly, since *R. dominica* is an insect pest capable of adapting to different climate conditions (Beckett *et al*., 1994; Walker and Farrell, 2003), its presence in these regions may contribute to aggravating the damage. What is more, stable levels of relative humidity in the southern and central regions may increase water content of the grains during storage. This is a risk factor in relation to insect infestation (Arbogast and Throne, 1997; Hagstrum *et al*., 2008). Contrary to the South and Center of the country; damage to farmer reserves was minimal in the northern region where climate conditions are less conducive to storage insect multiplication for many of the species.

Regarding economic losses, the study showed that paddy storage in Benin may lead to average economic losses of 2 FCFA (Franc of the African Financial Community) for each kilo of rice stored over 2- 3 months. This loss may reach 6 F, 9 F and 11 F per kilo of paddy for 4, 5 and 6 months of storage, respectively. In addition, on examination of losses after processing paddy, economic damage may reach 4 F, 9 F, 13 F and 17 FCFA $kg^{-1}$ of rice after 2, 4, 5 and 6 months of storage, respectively. As is the case for damage, economic losses to paddy caused by storage insect pests in Benin are higher for producers in the south than in the north. With the re-emergence of primary pest populations in many rice-producing zones

(Togola *et al*., 2010) and risks of dispersal to other, previously uninfested zones, losses may increase in the years ahead with a corresponding drop in producer income. For the time being, economic losses from quantitative loss caused by insect pest damage have not attained critical proportions amongst producers in the north. Similarly, where producers store for relatively short periods (2-3 months), the economic incidence of insect infestation is lower. However, when storage is for longer periods (4 months and more), there is a high risk of economic loss, especially for producers in the southern and central regions of the country. In these areas, major rice producers, farmer associations, processors and traders who store large stocks over long periods run the risk of non-negligible economic losses. The linear trend of losses in relation to storage duration proves without a doubt that storage duration is a major risk factor for post-harvest insect infestation, in general (Ngamo and Hance, 2007; Hagstrum *et al*., 2008) and for rice stored in Benin, in particular. Among survey respondents, 36.92% are aware of the economic impact of storage insect pests whilst more than half fear the effect of rodents. Indeed, contrary to rodents, storage insects often go unnoticed (Onolemhemhen *et al*., 2011) especially when they are at an immature stage. Under these conditions, damage may remain hidden much longer and thus escape the vigilance of the producers. Although rodents generally have a considerable economic impact on stored grains (Singleton, 2010), the role played by insects in weight and economic losses to stored rice in Benin remains a reality.

This scale of insect pest damage and the concomitant economic losses could mean that, as already observed, traditional varieties are increasingly abandoned for improved varieties which, in many cases, offer less natural protection against storage insects than does the former (Smale *et al*., 1995; Adda *et al*., 2002; Jones, 2012).

Apart from the substantive quantitative losses to stored grains that generally stem from insect damage (Subramanyam and Hagstrum, 1996), qualitative losses also take various forms notably, loss of seed germination capacity, product discoloration, change in taste, etc. These types of losses may lower the nutritional and organoleptic value of the rice (Jood *et al*., 1996), leading to a drop in market value and therefore, economic loss to producers, processors, traders and consumers (Onolemhemhen *et al*., 2011). All these harmful effects were to be taken into consideration, the economic impact could attain even higher proportions.

## CONCLUSION

This study produced an update on knowledge about quantitative and economic losses to stored paddy rice in Benin caused by insect pests. It also showed farmer perceptions of the economic impact of post-harvest insect pests. Among factors cited for increased quantitative and economic loss, mention should be made on climate conditions in the regions, insect behavior and anthropic causes (storage duration, abandonment of traditional varieties, neglect of damage caused by insects, etc.).

Judging from present losses, control measures should be adopted right away to limit an upsurge in post-harvest predators and protect stocks against multiple harmful manifestations. However, the cost of control measures should take into consideration the value of losses forestalled.

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