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Specific behavior of *Sitophilus zeamais* in the stocks of rice and maize in rural farmers at Bouaflé region, Côte d'Ivoire

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Key words: Storage, maize, rice, *Sitophilus zeamais*, specific behavior.

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Abstract

Analysis of the array of pests established S. zeamais (Coleoptera : Curculionidae) to be the principal pest which infects rice and maize storages and paves the way for the others insect pests' infestation. S. zeamais is followed by Tribolium castaneum (Coleoptera : Tenebionidae) and Rhyzopertha dominica (Coleoptera : Bostrichidae). In pure numerical terms with respect to infestation of rice and maize cereals in Bouaflé, the study revealed that S. zeamais represents an estimated 82.11 ± 12.40 % of the entire insect pests environment surveyed. Specific examination of the behavior of S. zeamais indicated that this insect pest population size varies over time throughout the storage period and is also responsive to the specific rice and maize species targeted. With respect to infestation of rice, the study found that infestation rate upon IDSA 85, IDSA 78 and WITA 9 was much lower than tan in the case of rice varieties NERICA, WAB 56-50 together with Zuna. Overall, infestation rate on maize has been found to be higher than that of rice.

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Introduction

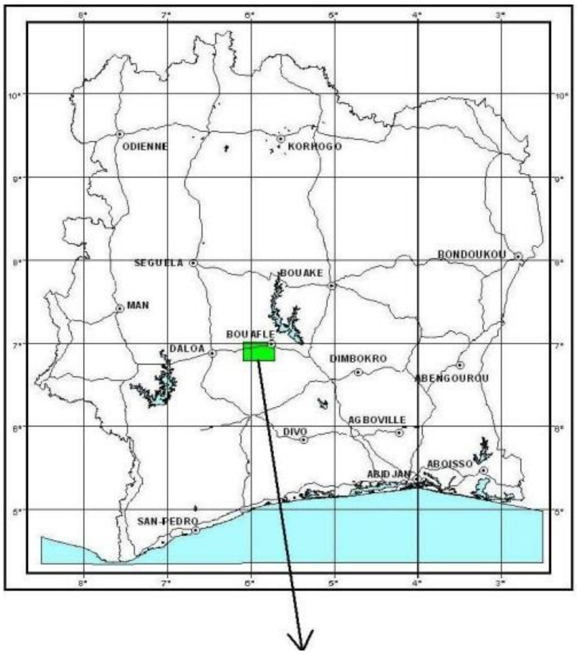
Rice (*Oryza sativa*), maize (*Zea mays*) and wheat (*Triticum sp*), are the most eaten cereals worldwide (Rouanet, 1984; Ratnadass, 1987; Anonyme, 2002a et 2002b). They are the staple food of sub-Saharan African population. Unfortunately, these cereals that are highly consumed undergo significant damage during their storage and conservation (Johnson, 2009). The post harvest loss emanating from poor storage and conservation conditions are estimated at nearly 1.3 billion of tons per year worldwide (Aphlis, 2012). Moreover, the lack of adequate structures compels farmers to sell their produce soon after the harvest. The combined effect of farmers having to sell their produce soon after harvest and the losses associated with poor storage impinges on the projected profit margins from these two crops. . In Côte d'Ivoire, like in countries in the south of the Sahara, the cereals are harvested and kept in condition of heat and humidity that paves the way for the development of harmful insects. Actually, storage conditions permit the development of rodents, toadstools and arthropods (Dust mite and Insects) causing losses estimated at 30 %, 26 % and 44 % respectively (Huignard, 1985; Foua-Bi, 1992).

Weevils belonging to the category of *Sitophilus* are listed among the insects responsible for the loss of rice and maize during their storage (Pantenius, 1988 a et b; Johnson *et al.*, 2012). This type includes three species, two of which [*Sitophilus oryzae* (L) and *Sitophilus zeamais* (M)] are responsible for major damages in tropical Africa. Contrary to *S. oryzae,* whose biology has been mastered, *S. zeamais* has hardly been the subject of any study in Africa. Studies of that species focus on assessing the damages caused in the post-harvest systems and the development of control methods associated with pesticide synthesis (Ratnadass, 1987; Affognon *et al.*, 1996). Specific studies aiming at pointing out the development of the behavior of *Sitophilus zeamais* during the storage of the cereals are needed in the context of Côte d'Ivoire in order to conduct an effective control of that insect pest.

Materials and methods

Study environment

Fields of rice and maize were created in the department of Bouaflé, in the center-west of between the north latitudes 6°30'and 7° and 5°30' and west longitude 6°30' (Chevalier, 1999). The observation sites, 89 in total, were dispatched among 17 villages in the region of Bonon and 13 villages in the south county of Ayaou (Fig. 1).



Côte d'Ivoire map

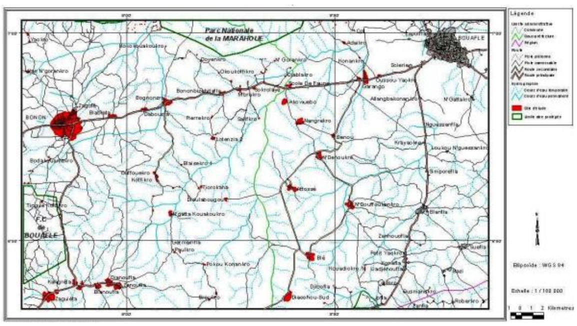


Fig. 1. Distribution map of sites (●) in the study area.

Data Collection

The animal biologic material consists of *Sitophilus zeamais* (Coleoptera : Curculionidae), one of the main insect pests of the cereal storages in Côte d'Ivoire as well as the insects listed in storages of rice and maize harvested on the observation site. The strains used were taken from stocks of rice and maize made immediately after harvest by farmers.

The plant biological material consists of nine varieties of rice, 6 of which have been certified by the West Africa Rice Development (WARDA), the National Agriculture Research Center (CNRA) and recommended by the National Rice Program (PNR). These are: IDSA 78, IDSA 85, NERICA 1, WAB 56-50 (upland rice) (Tableau 1) and BOUAKÉ 198, WITA 9 (irrigated rice) (Table 2). The three varieties of local rice (*Sahia, Blagonin* and *Zuna* are irrigated rice (Table 3) and have been used also.

Table 1. Characteristics of selected varieties of upland rice.

Variety	*Geographical origin*	*Species*	*Cycle (Days)*	*Resilience to drought*	*Average yield (t/ha)*	*Potential yielding (t/ha)*	*Size of the seed*
IDSA 78 or *Famosa*	CÔTE D'IVOIRE IDESSA-Bouaké	*Oryza sativa (Japonica)*	120-125	Good	2,5	5,2	Long enough and thin
IDSA 85 or *Guegbin*	BRAZIL	*Oryza sativa (Japonica)*	120	Good	2	3,5	Long and thin
NERICA 1 or *Bonfani*	WARDA - BOUAKE	*Oryza sativa* x *Oryza glaberima*	90	Good	4,3	4,8	Average
WAB 56-50	WARDA-BOUAKE	*Oryza sativa (Japonica)*	108	Fairly good	3,5	4	-

Table 2. Characteristics of selected varieties of irrigated rice.

Name of the variety	*Geographical origin*	*Species*	*Cycle (Days)*	*Resilience to drought*	*Average yield (t/ha)*	*Potential yielding (t/ha)*	*Size of the seed*
BOUAKE 189	INDONESIA IDESSA-Bouaké	*Oryza sativa (Japonica)*	125-130	average	4,5	8	Long and thin
WITA 9 or *Nimba*	WARDA-IITA (IBADAN NIGERIA)	*Oryza sativa (Japonica)*	120	Fairly good	6	10	long et thin

Table 3. Characteristics of local rice varieties.

Variety	*Geographical origin*	*Species*	*Cycle (Days)*	*Resilience to drought*	*Average yield (t/ha)*	*Potential yielding (t/ha)*	*Size of the seed*
SAHIA	UNKNOWN	Natural hybrid	120-135	Good	-	-	long and thin
BLAGONIN	UNKNOWN	Natural hybrid	120	Average	-	-	Short and big
ZUNA	UNKNOWN	Natural hybrid	120	Not good	-	-	Short and big

Two ecotypes of maize (The only ones used by the peasants) were used during this study. There are both the white and the yellow seeds of maize.

The technical equipment used consists of two polypropylene bags used to separate the cereals in portions of 5 kg. A MUNIGRAL (1800) brand automatic seed counter with a square shape mesh sieve measuring 2 mm each side was used to separate insects from seeds and a psychometer to gauge the temperature and the humidity of the breeding room. Two SARTORIOUS (BP 310 S) brand scales of precision 0.001 and 0.0001 have been used to weigh the seeds and the insects.

The experimental device consists of thirty three (33) samples of 5 kg of seeds taken from the different varieties of rice and maize put in polypropylene bags and arranged on shelves in a breeding room at an average temperature of 26.4°C ± 2.7 and a relative humidity of 84.5% ± 5.2.

Estimates of the number of individuals initially contained in the storages

Soon after the harvest, an estimate of the infestations and the number of adult insects contained in the portions was done after the inventory and the identification. This method to determine the initial infestation or the primary infestation has an economic interest and favors phytosanitary considerations for storage.

Monitoring the seeds and insect populations in the stocks

This study has helped appreciate the variation of the number of insects according to the time of storage. The purpose of this activity is to assess the damages done to the seeds in relation to the number of insects and established correlations between the numbers of insects at the time of storage and of conservation to the extent of damage. It led to the assessment of the variations of the numbers of the main insects present in the stocks of cereals studied.

Development of the number of insect populations during the storage

The objective of this study is to appreciate the level of infestation of the cereals and the fluctuation of the insect's population during the storage.

Before the storage, the insects were counted and put in portions respectively, in order to follow the variation of their number according to the initial infestation of each variety of cereals. Then, the bags are sealed. The number of insects is fixed after sieving, every 15 days, for 6 months. The numbering is done according to their species after a selection. For large numbers, the number of adult individuals per species is estimated according to the method used by Amevoin (1998) and Aboua (2004) and defined as follow:

$Nr = (Ne \times Pr)/Pe$ et $Nt = Nr + 2000$

With: Ne = Number of sampled insects (Ne = 2000 individuals); Pe = weight of the sample; Nr = Number of remaining insects; Pr = weight of the insects harvested;
Nt = total number of insects harvested.

Statistic Analysis

The analysis of the ascending classification, based on Ward's method was used to bring out similarities between different cereals pest insects. The Chi-square test was used to compare the degree of connection between the various insects harvested and the varieties of rice and maize grown. These analyses have been performed with Statistica 7.1 program.

Results

Relation between the insects and their hosts

The study of the pest insects of the stocks of rice and maize motivated the research on the relation that exists between the insects listed and the varieties of cereals available. So, the independence test of Chi^2 up to 5% gives a probability $p < 0.0001$. Chi^2 observed (1047.528) is different from Khi^2 calculated (113.145) with a degree of liberty (ddl') = 90. There is, therefore, a strong link between the insects and the varieties of rice and maize grown. Also, the similarity dendrogram based on Ward's method revealed two groups of insects. Group A consists solely of *S. zeamais* and group B which brings together all other insects, is divided into B1 with *Rhyzopertha dominica, Lophocateres pusillus, Carpophilus dimidiatus*, *Silvanus unidentatus* and B2 with *Cryptolestes pusillus, Tribolium castaneum and Sitotroga cerealella (*Fig. *2).*

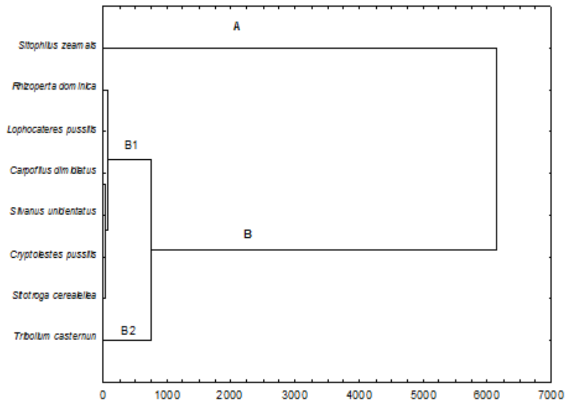


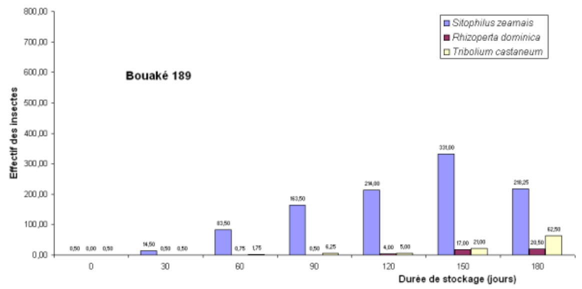
Fig 2. Similarity dendrogram showing the importance of Sitophilus zeamais compared to the others insects

Development of the population of Sithophilus zeamais during the storage

Irrigated rice

In the variety Bouaké 189, the population of *S. zeamais*, at the beginning of the storage (0.5 individual on average) evolved in three steps (Figure 3A). The increase in number is first slow till the 30th day with 14.5, and then it gets faster till the 150th day where it reaches the maximum of 331individuals and a fall in number (218.25 individual on average) on the 180th day. The population of *Rhyzopertha dominica* and of *Tribolium castaneum* remain low and starts to increase after 150 days with 20.5 and 62.5 respectively on the 180th day. On the variety Wita 9 (Figure 3B), the increase in the population is similar with that of Bouaké 189. The total number of *S. zeamais* which was an average of 1.5 at the beginning reaches a maximum value of 281.75 individuals after 180 days of storage. This number then decreases to 187 individuals after 180 days of storage. *Rhyzopertha dominica* and of *Tribolium castaneum* appear on the 150th day with total numbers of 27 and 25 individuals respectively.

A



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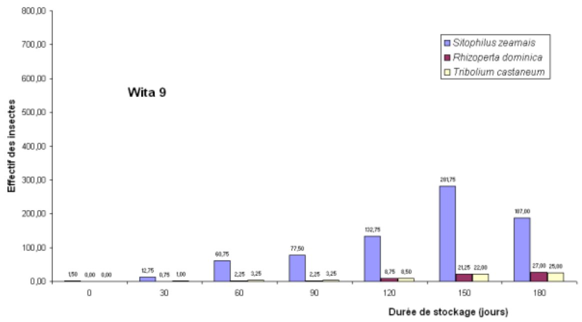
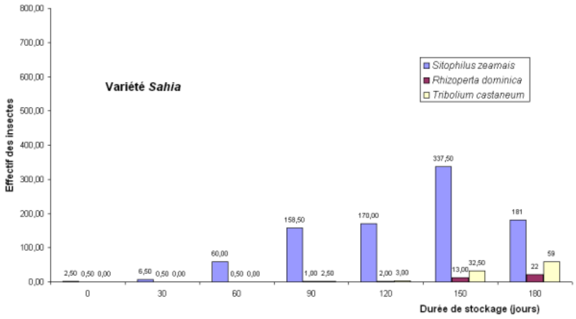


Fig. 3. Temporal distribution of insect populations in rice stocks grown in lowland

The variations of the number of insect's population throughout the time on the local variety *Sahia* is similar with the ones observed on the selected varieties (Figure 4A). The infestation begins with 2.5 individuals on average. It reaches its maximum value of 337.5 after 150 days of storage and drops to 181 individuals after 180 days of storage. Still, the behavior of *S. zeamais* on Blagonin variety (Image 4B) and Zuna (Figure 4C) differs from the previous ones. The maximum values are recorded after 180 days with average values of 355.25 on *Blagonin* variety and 566.5 individuals on *Zuna* variety respectively. Population numbers of *Rhyzopertha dominica* after 120 days of storage are 11 individuals and that of the *Tribolium castaneum* 150 days of 7 individuals on average. These populations increase fast to reach 24.75 on the 180th day on the variety *Blagonin* and 39 individuals on *Zuna* variety for *R. dominica*. As for *T. castaneum*, the maximum average values are 34.75 and 46 individuals on these two varieties of rice respectively.

A



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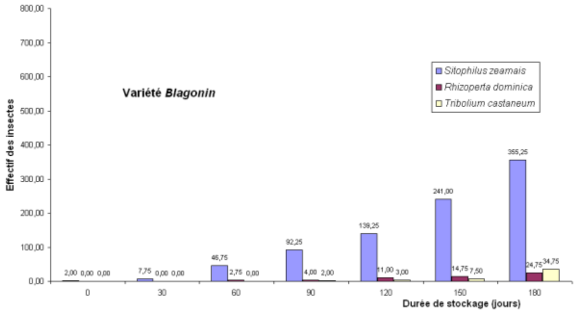

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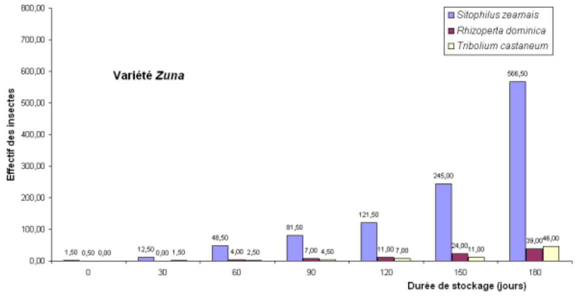
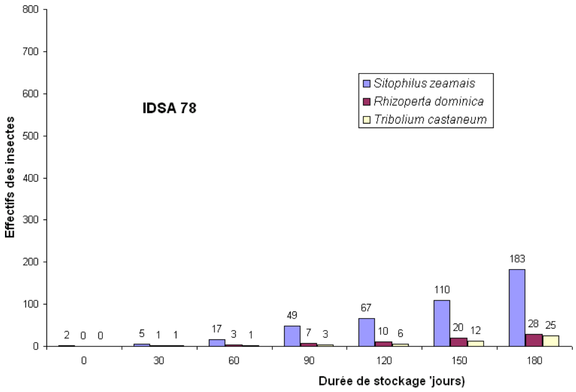


Fig. 4. Temporal distribution of insect populations in rice stocks grown in irrigated areas (local rice varieties)

A



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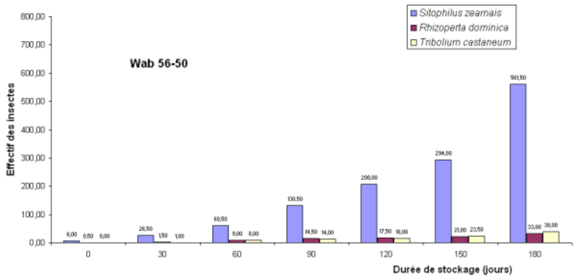
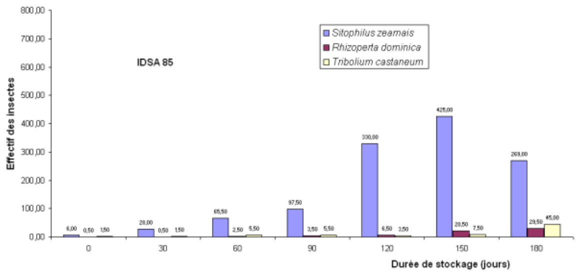


Fig. 5. Temporal distribution of insect populations in upland rice stocks

A



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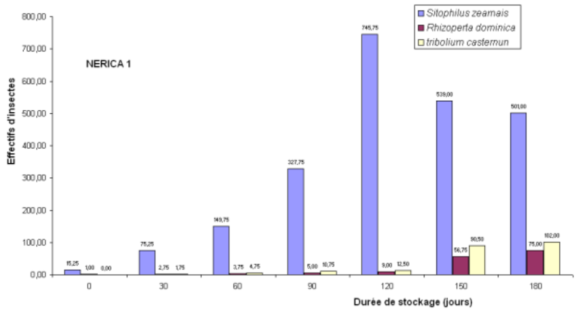


Fig 6: Temporal distribution of insect populations in upland rice stocks

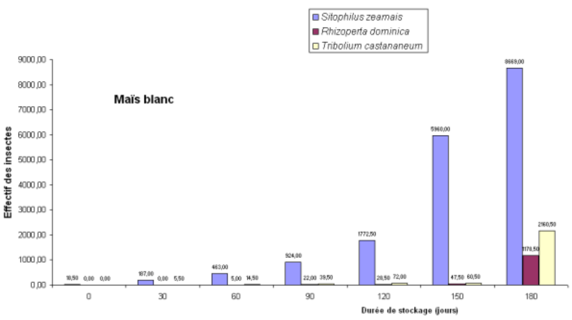
Ecotype of maize

In the portions of white maize, *S. zeamais* population in the stock is 18.5 individuals on average. It increases rapidly to reach a total number of 8,669 after 180 days of storing. Yellow maize experiences a similar increase in *S. zeamais* population with 16 individuals at the beginning and a maximum of 7,093 individuals at the end of the storage (Figures 7A and B).

Upland rice

For the varieties 78 IDSA and Wab 56-50, the increase in *S. zeamais* population size is regular (Figures 5A and B). It reaches its maximum of 183 individuals after 180 days after storage for IDSA 78 and 561.50 individuals on average for 56-50 Wab. On the variety IDSA 85 (Figure 6A), the initial population of *S. zeamais* is 6 individuals. This population grows rapidly and reaches a total member of 425 individuals after 150 days of storage and then decreases thereafter down to 269 individuals after 180 days. The total membership of *R. dominica* is 20.50 individuals after 150 days compared to *T. castaneum* which has 7.5 individuals during the same period. It increases more rapidly and reaches 45 individuals after 180 days of storage. On the NERICA 1, the size of the *S. zeamais* population increases more rapidly (Figure 6B). An average initial population of 15.25 individuals, the number reaches 745.75 individuals after 120 days. Then the population drops to 501 individuals on the 180th day after storage.

A



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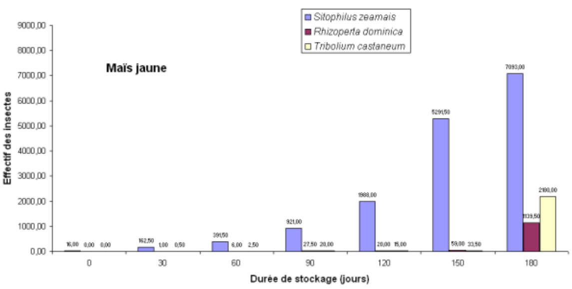

Fig. 7. Temporal distribution of insect populations in corn stocks.

Discussion

The stocks of rice are infested by the insects whose number increases as time goes on. The main insect pests encountered are the same on both rice and maize. These are *Sitophilus zeamais, Rizopertha dominica and Tibolium castaneum*. However their development varies according to the type of cereals. The prevalence of *S. zeamais* compared to *T. castaneum and R. dominica* could be explained by the relatively high initial population recorded at the beginning of storage. Indeed, the development cycle of the species is short and lasts about a month thus favoring an appearance rate of generations of this species whose numbers are higher during storage in the portions made. This is materialized by the saturation of insects in stocks where high numbers in the environment can produce a mass effect and both intra and interspecific competition.

This saturation is thus accompanied by a high mortality of *S. zeamais* in the same period. Therefore the insect population starts to drop. Our observations are consistent with those of Ratnadass (1984) who reported that overcrowding in weevils causes an interruption of copulation; as a consequence, females remain virgin. Moreover, the egg-laying with gravid females is disrupted, following an unrest caused by overpopulation. This will inevitably lead to a reduction in the number of individuals of the subsequent generations. In addition, the lifespan of a *S. zeamais* is 4 months on average, which favors a long period of oviposition. This factor is associated with a high rate of fecundity with 400 eggs per female. In addition, its embryonic and post-embryonic development is relatively short (Delobel and Tran, 1993; Koussou and Aho, 1993; Danho, 2003 and Johnson, 2009). These factors make room for the appearance and overlap of generations in time. The number of *S. zeamais* in stocks of commodities increase on the 4th, 5th and on 6th month of storage for some varieties of rice, and until the sixth month for maize varieties. Moreover, a drop in its population could also subsequently be explained by the development of parasitism due to Hymenoptera and Diptera which are parasitoids growing at the expense of insects in the stocks. They play a regulatory role in reducing attacks by lowering the number of pests. The decrease in the number *of S. zeamais* could also be the result of a phenomenon of balance between food availability and the recorded parasite load leading to a food recession. It was shown on the observation site that when the population of cochineal in cassava (*Phenacoccus manioti*) decreases, those of the predatory ladybird associated with it (*Exochomus convanus*) also decrease. These insects migrate and return when the conditions are favorable (Namkosserena*, 1994*). These results are similar to those obtained in the same situation. Indeed, *T. castaneum*, feeds itself on the remains left by the *S. zeamais*. Therefore, the more they will be debris, the greater the development of the secondary insect pest associated will be.

Along with the decline in the size of *S. zeamais*, after 150 days of storage (for some varieties of cereals) , the number of *T. castaneum* increases. This same situation was reported by Ratnadass (1984) who worked on different varieties of cereals in Côte d'Ivoire and in the Central Africa Republic (CAR). However, the time of occurrence of *T. castaneum* differs depending on the commodity. In the portions analyzed, the presence of this insects pest has been recorded at the time of storage for some varieties (NERICA 1, WAB 56-50 and *Sahia*). But in most cases, its presence was observed during the first months with very low numbers. Also, the fall in the number of *S. zeamais* does not cause *T. castaneum* to drop. That shows that the two insects, although they are insect pests, do not behave the same way in the stock. Indeed, *T. castaneum*, secondary insect pest feeds itself on broken and damaged kernels left by the first; *S. zeamais* is a primary insect pest (Koussou and Aho, 1993).

The numerical gap between *S. zeamais* and R. *dominica*, both primary insect pests could be explained by the very low initial infestation of *R. dominica*, starting in the fields. Indeed, the development of two species meets the same requirements and occurs in the same environmental conditions (Koussou and Aho, 1993). However, while the female of *S. zeamais* lays its eggs inside the grain, thus securing its eggs and larvae, the female R. dominica lays its eggs outside the seeds. Its larvae are therefore more vulnerable than those of *S. zeamais*.

These observations are consistent with those of Biliwa and Richter (1990) and that Agbaka (1996) who believed that when two species compete, the one which is more numerous at the beginning grows more rapidly and supersedes the other. Unlike *S. zeamais*, the action of *R. dominica* comes late. Koussou and Aho (1993) reported that the seed infestation by *S. zeamais* occurs early at the stage of drying up. Like Nwana and Akibo-Betts (1982), the observations made during the denudation of the samples before and during storage have shown that some varieties were more infested than others. In the group of irrigated rice, the number of insect population recorded on the selected varieties is low, compared to those of the local varieties, except the local *sahia,* that experienced fewer attacks. Thus, Troude (1982) and Ratnadass (1984) define the local varieties as a result of mass selection oriented toward rusticity, thus less vulnerable and able to guarantee the durability of the species despite the low yield. *Sahia variety* is a traditional variety from Bonon. The varieties such as *Blagonin* and *Zuna* experienced higher infestations while the local varieties are supposed to be more resilient. The latter ones would be the result of a hybridization of local wild varieties and those selected previously introduced and that have lost their original rusticity. To Haines (1981a) the high- yielding varieties selected are often more vulnerable than the traditional varieties are.

Regarding upland rice, the infestations that occur during the storage are more critical than those recorded on varieties of irrigated rice. This could also be explained by the type of rice farming, which would influence the water content of the grain. In fact, for its synthesis in water, *S. zeamais*, is said to damage more starch in upland rice, more infested than the irrigated rice whose content in the water would be higher and therefore less infested. Furthermore, the preponderance of infestations on maize could be explained by the lack of a protective cover on the maize unlike various rice varieties that are protected by a shell (Johnson, 2009).

Conclusion

Stock monitoring has helped highlight the levels of population fluctuations of the three main species of insects encountered and their relative importance during the storage period. The three main insects in cereal stocks studied are *Sitophilus zeamais* (which found itself relevant by its relative importance) followed by *Tribolium castaneum* and *Rhyzopertha dominica*. The behavior of *S. zeamais* on some types of grains differs from that other insects. Being less numerous at the beginning of the storage, *S. zeamais* population reaches a high level on the 150th day then and declines thereafter. As for *T. castaneum* and *R. dominica,* they appear quite clearly on the 150th day of storage and continue to increase in number with a smaller population, compared to that of *S. zeamais*.

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