

Evaluation of Biopesticides for Sustainable Management of Food Stocks in Rural Area in Bouaflé, Center-west, Côte d'Ivoire

Johnson Félicia*

Laboratory of Zoology and Animal Biology,
F.H.B University, UFR-Biosciences, E-mail:
felijohnson@yahoo.fr, Phone:
+ 225 40 212 475, Côte d'Ivoire

Boga Jean Pierre

Laboratory of Zoology and Animal
Biology, F.H.B University, UFR-
Biosciences, Côte d'Ivoire

**Ouali-N'goran San-Whouly
Mauricette**

Laboratory of Zoology and Animal Biology,
F.H.B University, UFR-Biosciences, Côte
d'Ivoire

Tano Yao

Laboratory of Zoology and Animal Biology,
F.H.B University, UFR-Biosciences, Côte
d'Ivoire

Fouabi Kouahou

Laboratory of Zoology and Animal Biology,
F.H.B University, UFR-Biosciences, Côte
d'Ivoire

Abstract – The issue of food security remains a major challenge in various regions of the world particularly in Africa south of the Sahara. Unfortunately, in Côte d'Ivoire, cereals production does not satisfy the needs of populations because of post-harvest losses due to insects and other pest bodies. In order to develop alternatives to secure food, a sealed attic was built. Biopesticides made from the leaves of 7 plants (*Ocimum gratissimum*, *Ocimum canum*, *Lippia multiflora*, *Hyptis suaveolens*, *Mentha piperita*, *Crotalaria retusa* and *Azadirachta indica*) have been used to test their insecticidal effect on *Sitophilus zeamais*, major pest of grain stocks. The results showed that these plants reduce the lifetime of the insect to 96.61%. The use of these biopesticides associated with improved attic has allowed secure 74.32% of the stock. This approach could therefore constitute an ecological and sustainable control strategy, viable for the protection of stored products.

Keywords – Food Security, Cereals, Insects' Pest, Evaluation of Biopesticides, Sustainable Control.

I. INTRODUCTION

The West African region is subject to recurrent crises affecting agricultural production and food security leading to a delay in the achievement of the Millennium Development Goals (MDGs), on the fight against hunger. In Côte d'Ivoire, rice and maize are important economic and social issues ([1], [2]). They are the staple food for three quarter of the Ivorian. Thus, during 2002, rice production in Côte d'Ivoire was estimated to 545606 tons; this production grown over the past years to reach 640 213 tons in 2005 [3]. At the national level, the average production of the maize was estimated in 2005 to 631000 tons with an average area of 295000 hectares. Yields improved but remain low (1.45 tons/ha). The food balance sheet of the maize is positive. However, the country is still importing maize from European countries for specific needs (industry, breweries etc.) ([4], [5]). Production efforts of these two foods are far from meeting the needs of the Ivorian population. To nowadays, Côte d'Ivoire continues to import huge quantities of rice from other producing countries ([6], [7], [8]). The volume of rice imports is around 796,000 tons and represents about 113

billion of CFA ([6], [7]). These numbers are constantly growing and reached in 2007 a total of 150 billion of CFA with around 808,781 tons imported [2]. This strong dependence on importations puts the country in a situation of food insecurity.

Beyond the main challenge that represents food security policies at national level, the rice remains an important source of income for the farmers. Unfortunately, due to the lack of efficient conservation strategies, producers have to sell their products very early. Therefore, speculation around this product does not provide farmers with the expected financial advantage. These constraints remain a major problem that may hinder the objectives of food security.

Furthermore, to address the importance of post-harvest losses due to the insects in stocks, control measures are essentially based on the uncontrolled use of synthetic pesticides including persistent organic products (POPs). As a consequence, foods are contaminated by toxic residues, causing serious harm to consumers and users ([9], [10], [11]), but also on the environment by the accumulation of toxic compounds in the ecosystems. In light of those negative consequences associated with the use of synthetic pesticides, there is an urgent need of new, environmentally, friendly and cheap alternatives. Among those alternatives, plants with insecticidal and/or insectifuge effects against crop pests may be a viable alternative. Studies of the biological activity of some plant species have shown that they may validly substitute synthetic insecticides ([12], [13], [14], [15], [16], [17], [18], [19]).

Certainly, the reduction of post-harvest losses call for the promotion of effective control methods, less toxic and less expensive for the farmers but also by improving the storage infrastructures. However, the scientific literature is relatively silent on the most appropriate strategies to be implemented taking into account the level of education of farmers and their cultural habits; dealing with the valorization criteria of the substances coming from local plants for a specific protection of stored food against crop pests.

How to articulate such a strategy that could take into account both, the design of storage infrastructures most suitable and the rational use of local plant substances? How to guarantee to the population a longer period of cereals storage and allow them to obtain the added value on their products, by selling them when the demand is higher than the supply on the market?

The current study was designed to assess sustainable control strategies based on the use of biopesticides in the post-harvest protection of the stored foodstuffs in rural Côte d'Ivoire. This is an integrated intervention combining the improvement of storage infrastructures and the use of local plants for their insecticidal and/or repellent effects against crop pests.

II. MATERIEL AND METHODS

The animal material is represented by all insect pests, especially *Sitophilus zeamais* (Coleoptera: Curculionidae) one of the main insect pests of grain stocks in Côte d'Ivoire and particularly in Bouaflé district. The strain used in the current study derived from rice stocks made immediately after harvest by Bonons' farmers.

The vegetable material was composed of rice grains and the plants to be tested. The variety of rice used (NERICA 1) is certified by AfricaRice and the National Agricultural Research Centre (CNRA) and recommended to the farmers and to the agricultural cooperatives by the National Rice Program (NRP). This variety of rice was followed during storage and conservation, in order to evaluate its sensitivity to the insects, mainly *Sitophilus zeamais*, and the damages caused by this aforementioned insect. The plants used for the tests are from: Dimbokro region (*Ocimum gratissimum*, *Ocimum canum*, *Lippia multiflora*), Bouaflé region (*Hyptis suaveolens* and *Crotalaria retusa*), Yamoussoukro district (*Azadirachta indica*) and Abidjan district (*Mentha piperita* from the local market of Adjamé a neighbour of Abidjan district). The selection of these plants was based on their use by the farmers and the findings from previous studies ([20], [17], [18]).

A. Experimental Approach

To meet with the needs of the people visited in term of storage infrastructures, we propose to build another type of storage infrastructures which allows a good conservation of the grains produced. This is a sealed attic with walls preventing against animal and humidity (see Figure x).

B. Preparation of Powders of Plants Used

The leaves from the harvested plants are dried at ambient conditions, at an average temperature of 20 ± 2 °C and a relative humidity of $75 \pm 5\%$. The leaves were from *Ocimum gratissimum*, *Ocimum canum*, *Lippia multiflora*, *Hyptis suaveolens*, *Mentha piperita*, *Crotalaria retusa* and *Azadirachta indica*. They were subsequently powdered. The powders obtained were used for the different tests in order to assess the direct effect of plants on some biological parameters of the insects. The K-Othrine 0.2 PP was also used as a reference powder in order to compare its effect with those of vegetable powders.

C. Toxicity Assessment

We were aiming to assess the effect of the powder on the biological parameters of the insect (mortality rate, lifetime, period of development and emergence times) and on the duration of storage of the rice. Previously packaged, 100 g of rice grains are placed in each twenty-five (25) containers. Each container received an amount of 0.25; 0.50 and 1 g of powder and mixed so that all the grains are coated by the powder particles. One of the boxes served as a control and do not receive the powder. Each tested box received 10 pairs of newly emerged insects. The boxes are monitored every 24 hours until the death of the last insect. This process was repeated three times. The average life span is calculated after counting dead insects and the reduction rate was also assessed.

D. Assessment of Biopesticides in Field

This study was design to evaluate the efficacy of the new storage infrastructures compared with the former ones used by the farmers based on the sanitary condition, the infestation rate, grain weight loss and the duration of the conservations. In order to compare the state of rice's seed at the end of the storage in both types of structure, seventy-one (71) and twenty (20) bags of 50 kg of rice, (Which corresponds to 3550 kg and 1000 kg of rice, respectively), were purchased and stored in the new structure and in the structures used by farmers. The seeds were treated with the powder of tested plants at the amount of 1 g of powder per 1 kg of paddy. All stocks are regularly visited and surveyed. Regularly, samples were routinely taken on each bag and seeds were analyzed.

E. Statistical Analysis

Data were entered twice in Excel spreadsheets and cross-checked in EpiInfo to assess the consistency. Qualitative data were expressed as proportions and compared by Pearson test. Qualitative data were expressed as means. The analysis of variance (ANOVA) was used to test the significance level between the different averages. Student-Newman and Keuls tests (homogeneity test) at 5% threshold was used to compare the results obtained after the application of plants' powders and effects of plants were classified according to the doses of powders applied. All the tests were performed with STATISTICA Version 7.1 software.

III. RESULTS

A. Implementation of the New Storage Structure

The storage structure is designed to prevent access of rodents and insects. It allows good ventilation and prevents stocks rise in soil moisture, thus avoiding mold and rotting of grains. Concerning the rise in humidity, special arrangements are made. It is installed in the ground at the time of the establishment of the foundation, a waterproof plastic canvas. To prevent access of rodents, the attic door, 1.5 m length dimensions of 0.85 m in width, is mounted on a low wall with a height of 0.5 m. At the top of walls, no opening should let pest organisms. All spaces are closed; it is a hermetic structure. Under these conditions, the vents are open on each side to allow

circulation of air and a ventilation stock avoiding condensation of water vapor, which may lead to wetting of the commodity supporting mold growth. These vents are fitted with barred windows. The outer fence metallic mesh 2 x 2 cm prevents the ingress of rodents. Inside, these windows have grilles with mesh (1 mm) cannot let insects. In sum, the attic is sealed, walls and openings do not let in animals and the floor prevents rising damp. For field testing, shops cinderblock (cement brick) 400 x 400 x 250 cm with a metal roof were built. These structures may contain up to 5 tons of grain.

B. Efficiency of Plant Powders on Biological Characteristics of *Sitophilus Zeamais*

The effect of powders of some plant species of local flora, compared with deltamethrin (K-Othrine 0.2 PP), synthetic insecticide used by farmers, was tested in order to assess their effectiveness on some biological parameters of main pest of maize weevil grain in Côte d'Ivoire. The lifetimes obtained with the powders tested are between 3.05 ± 0.43 days (with 1g of *M. piperita*) and 31.8 ± 4.31 days (with 0.25 g of *L. multiflora*) either the reduction rates of 96.61 and 64.67% respectively. All applied powders reduced the life of the insect. With the K-Othrine, the life of the insect was 2.30 ± 0.37 , representing a 97.44% reduction rate (Table I). The powders also lengthen the average length of insect development, irrespective of the product used. Longer development times were achieved with the highest doses. Thus, at a dose of 1 g, the values of the average development period

were between 41 ± 7.93 for *O. canum* and 46.5 ± 4.18 days for *M. piperita*. Low doses (0.25 g) yield 39 days development time. Treatment with K-Othrine causes the death of all individuals before the lay eggs (4 days) (Table II).

C. Evaluation of Storage Infrastructures

The infection rate of the rice purchased was 100% with the weight losses ranged between 72 and 80% with a mean value of $74.7 \pm 4.16\%$ (Table III). The average weight at the end of the experimental storage was 12.65 ± 2.08 kg for a 50 kg bag. In contrast, the improved storage structures, shown an infection rate set between 0 and 5% with an average value of $3.1 \pm 2.02\%$. Weight losses were between 0 and 0.8% with an average value of 0, $38 \pm 0.33\%$ and an average weight at the end of the storage of 49.81 ± 0.16 kg for 50 kg bag (Table III). The use of local plants powders as biopesticides in improved storage structures helped secure 37.16 kg of seeds per bag; which was estimated to an embodiment of 74.32% gain.

IV. DISCUSSION

The infestation rate, the weight at the end of storage and the weight losses obtained during the evaluation of the strategy based on the use of biopesticides plants in the newly built structures are statistically different from those recorded in the old storage structures.

Table I: Effect of powders on the lifetime (days) of *S. zeamais*

Product	Powder doses (g)			Control
	0,25	0,5	1	
<i>K-Othrine</i>	2.80 ± 0.38 b (-96.89)	2.50 ± 0.35 b (-97.22)	2.30 ± 0.37 a (-97.44)	
<i>M. piperita</i>	12.50 ± 1.7 g (-86.11)	7.65 ± 1.13 f (-91.50)	3.05 ± 0.43 c (-96.61)	
<i>O. canum</i>	12.80 ± 0.69 l (-85.78)	10.00 ± 0.0 j (-88.89)	5.00 ± 0.0 h (-94.44)	
<i>O. gratissimum</i>	13.90 ± 0.53 k (-84.56)	11.10 ± 0.65 i (-87.67)	7.20 ± 0.41 g (-92.00)	90 ± 18.32
<i>A. indica</i>	14.75 ± 0.96 f (-83.61)	10.75 ± 0.78 e (-88.06)	10.75 ± 0.78 d (-88.06)	
<i>C. retusa</i>	16.10 ± 2.21 p (-82.11)	15.00 ± 2.01 ml (-83.33)	10.90 ± 1.77 f (-87.89)	
<i>H. suaveolens</i>	17.00 ± 0.66 n (-81.11)	13.50 ± 0.6 f (-85.00)	3.00 ± 0.56 o (-85.56)	
<i>L. multiflora</i>	31.80 ± 4.31 q (-64.67)	26.70 ± 3.60 q (-70.33)	23.95 ± 3.24 q (-73.39)	

Numbers in brackets: lifetime rate reduction (%). Average of three repetitions \pm SD (n = 60) Comparison of means between rows and columns by the Student-Newman-Keuls test at the 5% (F = 24.49641; ddl = 7; p = 0.000000). In the same column, the assigned values of the same letters are not significantly different. In the same line, the assigned values of the same letters are not significantly different.

Table II: Effect of different treatments of powder doses on the average duration of development (days) of *S. zeamais*

Powder dose (mg)	Plant species								Control
	<i>Mentha piperita</i>	<i>Ocimum canum</i>	<i>Ocimum gratissimum</i>	<i>Hiptys suaveolens</i>	<i>Lipia multiflora</i>	<i>azadirachta indica</i>	<i>Crotalaria retusa</i>	<i>K-Othrine</i>	
0.25	$39.5 \pm 8.8f$	$39.5 \pm 8.8f$	$39.5 \pm 8.8f$	$39.5 \pm 8.8f$	$39.5 \pm 8.8f$	$40 \pm 8.8e$	$39.5 \pm 8.8f$	-	32.5 ± 5.18 g
0.5	$39.5 \pm 8.8f$	$39.5 \pm 8.8f$	$39.5 \pm 8.8f$	$39.5 \pm 8.8gf$	$44.5 \pm 8.8b$	$40 \pm 8.8e$	$39 \pm 8.51f$	-	
1	$46.5 \pm 4.2a$	$43 \pm 1.6c$	$41 \pm 7.93d$	$42.5 \pm 6.49c$	$44.5 \pm 5.92b$	$41.5 \pm 7.64d$	$44.5 \pm 5.91b$	-	

Average of three repetitions \pm SD (n = 60)

Comparison of means between rows and columns by the Student-Newman-Keuls test at the 5% (F = 24.49641; ddl = 7; p = 0.000000)

In the same column, the assigned values of the same letters are not significantly different

In the same line, the assigned values of the same letters are not significantly different.

Table III: Infestation rates and weight loss of cereals in improved and traditional conservation structures

Repetition	Improved structure				Traditional structure		
	Initial weight (kg)	Infestation rate (%)	Final weight (kg)	Weight loss (%)	Infestation rate (%)	Final weight (kg)	Weight loss (%)
R1	50	2	49.8	0.4	100	10	80
R2	50	5	49.8	0.4	100	14	72
R3	50	0	50	0	100	15	70
R4	50	5	49.5	1	100	15.5	69
R5	50	2	49.9	0.2	100	14	72
R6	50	0	50	0	100	13	74
R7	50	5	49.6	0.8	100	10	80
R8	50	3	49.9	0.2	100	13	74
R9	50	5	49.9	0.2	100	10	80
R10	50	4	49.7	0.6	100	12	76
Mean	50	3.1 ± 2.02	49.81 ± 0.16	0.38 ± 0.33	100	12.65 ± 2.08	74.7 ± 4.16
P-value at the 5% threshold					0.0000	0.0000	0.0002

This approach allows inferring that the results obtained in the search of innovative solutions were satisfactory and were very efficient.

These findings are similar to those of Boxall [21] who found that the estimate of weight loss could be used to evaluate the adaptation of the proposed solutions and to identify the most appropriate method for the given context. This strategy reduces post-proofed losses and secures the production to ensure food and income for people.

It is by researching appropriate approaches that some researchers and policy makers in developing countries have agreed on the fact that the reduction of post-harvest losses is of strategic importance for developing countries [22].

The construction of suitable storage structures and the introduction of plants with insecticidal and/or repellents effects could significantly improve the storage of cereals. These plant substances could be described as "biopesticides". This approach has a clear comparative advantage and a real added value. Those "biopesticides" could supplement synthetic insecticides sold in the market and commonly used by farmers for the protection of stored products against insect pests. Unfortunately, among farmer communities, the use of prohibited synthetic pesticides which should not be used for stored products due to the toxicity and health hazards they pose to human health are widely promoted and sold on markets [1].

In addition, main attacks in storages are carried out by weevils, such as maize weevil species *Sitophilus zeamais* that reinfests whole stock in a short time. The fumigation of traditional attic is the main mean of control used by producers. It is relatively effective in preserving maize stored less than 6 months. This proven conservation strategy assessed during this study is sustainable, and could help to develop a combination of measurements and control methods for an appropriate management adapted to the socio-economic systems of the farmers. This approach is similar to that proposed by Affognon et al. [23] who suggest an adaptation of new approaches to the socio-

economic conditions of the farmers. Thus, adoption of preventive control in the strategy of sustainable conservation is proven and justified because it can help to detect very early infestations. This argument is consistent with that of Boxall [21] for which the method also avoids the risk of cross-contamination of grains.

Control methods based on the use of local materials as alternatives and qualified as reasoned control has been advocated. The use of natural substances associated combined with some improvement in the storage infrastructures demonstrated same findings as in the current study ([24], [25], [26]).

The toxicity of these natural substances is considered negligible or less important because of the medicinal properties of the plant species used. These plants are used for their therapeutic properties both in rural and city. Stéphane [25] reports that the consumption of these local plants by children and adults does not result in a manifestation or intoxication signs. However, farmers still use tirelessly synthetic insecticides to protect stored products. During the experiments, evaluating of the effectiveness of plant powders from various local plants on populations of *S. zeamais* with the *Mentha piperita* powder we found substantially equal effectiveness to that of K-Othrine 0.2 PP (deltamethrin).

These observations are similar to those reported by Stéphane [25] who compared the respective effects of neem powder, the hexachlorohexane (HCH) and the malathion in the maize stocks protection against *Sitophilus* spp. The repellency and antifeedant contact of certain compounds of neem stop the development and reduce female fertility by blocking certain hormones involved in the reproduction of the insect.

• Implication to Research and Practice

Sustainable control methods combined physical fight and the use of plants as biopesticides in improved storage structures that reflect the realities of the farmer's world. Such provisions could prevent the systematic use of synthetic pesticides in controlling pests in stored food.

This new approach could help to promote the trade of rice and to boost the agenda of NRP (National Rice Program) at national level, AfricaRice at regional and even beyond by IRRI (International Rice Research Institute) in Philippines. It allows to extend the storage and preservation of food stored while improving traditional storage practices.

V. CONCLUSION

The advantage of this approach is to reduce the risk of poisoning by improving the gain in grain stocks. Thus, farmers could provide to their families a food security. They could also wait until the lean season, when foods are scarce on the market to sell their products in order to achieve substantial gains and improve their living conditions. This improved attic that was designed and tested for the purposes of this study, overcome the gaps of the existing structures, traditional attic and call for improved structures. This study also provides the advantage to open another field of exploration.

Studies of local plants powders are worth considering. Also, to reduce the problem related to the loss of crop products and meet the people of cereal consumption needs (rice and corn) it would be necessary to look for varieties of rice and corn resistant to insect attack. Furthermore, to solve the problems of deprecation of these commodities and face the environmental challenges it would be interesting to make available the extraction of essential oils in order to reduce the systematic use of synthetic pesticides.

An assessment of an integrated strategy for hardier rice varieties to insect attack would be a useful contribution. It seems appropriate to promote the creation of garden plants with insecticide and/or insect repellent effects to protect stocks of crop products and to avoid the systematic use of synthetic insecticides, which is harmful to humans and the environment. The appropriation by the rural world of this approach opens up an interesting way to solve the problems of the protection of stored foods and the environmental pollution.

VI. ACKNOWLEDGMENT

The data upon which the study was framed was collected through a United Nations Development Program Small Grant Project which was executed in Côte d'Ivoire from 2002 through 2008. Project activities were carried out in collaboration with the Ivorian government and Winrock International per the agreement under contract number: Project IVC/98/G52 No COT/02/12. The authors wish to express their sincere gratitude and appreciation to UNDP-GEF for its seed founding and also wish to thank the field collaborators for their useful contributions.

REFERENCES

[1] Anonyme, Diagnostic de la filière maïs en Côte d'Ivoire, 2014, 58 P Available <http://www.futurasciences.com/magazines/environnement/infos/>

[2] Anonyme, Evolution de la production et des importations de riz en Côte d'Ivoire de 1265 à 2008. Edition BUPED, 2009, 29 p.

[3] Anonyme, Annuaire des statistiques Agricoles. Ministère de l'Agriculture. Les séries Staf Agri. Edition Février 2007, Direction des statistiques, de la documentation et de l'informatique, Côte d'Ivoire 2007, 87 p.

[4] CNRA, La production du maïs en Côte d'Ivoire 2014 Available : <http://www.cnra.ci/descprog.php>.

[5] CNRA, Bien cultiver le maïs 2014, Available : http://www.erails.net/images/cote-divoire/cnra/cnra/file/cultiver_maïs.pdf

[6] Anonyme, Statistiques douanières. INS, PNR République de Côte d'Ivoire, 2004, 1p.

[7] Anonyme, Riz : les revers d'un succès : *Spore, 2005, 115 : 4-5.*

[8] C. Koffi, et A. K. N'dri, Marché et commercialisation du riz local au centre-ouest de la Côte d'Ivoire, *AGRON. AFR.*, 2006, XVIII (3). 299-308.

[9] R. Kumar, La lutte contre les insectes ravageurs. La situation de l'agriculture africaine. Ed. Karthala et C.T.A., 1991, 6-160.

[10] T.G., Momar, S. Dogo, W. Jean-Paul, et L. Georges, Lutte contre les ravageurs des stocks de céréales et de légumineuses au Sénégal et en Afrique occidentale : synthèse bibliographique. *Biotechnol. Agron. Soc. Environ.*, 2011, 2011 15(1), 183-194.

[11] P.S. Cissokho, T.G. Momar, S. El Hadj, et D. Karamoko., Substances inertes et plantes à effet insecticide utilisées dans la lutte contre les insectes ravageurs des céréales et légumineuses au Sénégal et en Afrique de l'Ouest. *Int. J. Biol. Chem. Sci.*, 2015, 9(3): 1644-1653.

[12] R. C. French, The bio-regulatory of flavour compounds on fungal spores and other propagules. *Am. Rev. Phytopathol.*, 23 : 173-199.

[13] G. Riba, et C. Silvy, Combattre les ravageurs des cultures : enjeux et perspectives. Edition INRA, 1989, 230 p.

[14] S. Gakuru, et K. Foua-Bi, Effet comparé des huiles essentielles de quatre espèces végétales contre la bruche du niébé (*Callosobruchus maculatus* FAB) et le charançon du riz (*Sitophilus oryzae* L.). *Agricultures*, 1995, 13 (4) : 143-146.

[15] I. A. Glitho, K. G. Ketoh, et H. K. Koumaglo, Effets de quelques huiles essentielles sur l'activité reproductrice de *Callosobruchus maculatus* Fab. *Ann. Univ. de Ouagadougou, Série B*, 1997, 5 :174- 185.

[16] K. G. Ketoh, Utilisation des huiles essentielles de quelques plantes aromatiques du Togo comme biopesticides dans la gestion des stades de développement de *Callosobruchus maculatus* F. (Coleoptera : Bruchidae). Thèse de Doctorat Univ. du Bénin, Lomé-Togo, 1998, 136 p.

[17] B. Seri-Kouassi, Entomofaune du niébé (*Vigna unguiculata* L WALP) et impact des huiles essentielles extraites de neuf plantes locales sur la reproduction de *Callosobruchus maculatus* FAB (Coleoptera : Bruchidae) en Côte d'Ivoire. Thèse de Doctorat d'Etat ès sciences, Université de Cocody, 2004, 199 p.

[18] F. Johnson, B. Seri-Kouassi, L. R. N. Aboua, et K. Foua-Bi, Utilisation de poudres et d'extraits totaux issus de plantes locales des genres *Ocimum* et *Mentha* comme biopesticides dans la lutte contre *Callosobruchus maculatus* FAB. *AGRON. AFR.*, XVIII (3) : 2006, 221-233.

[19] F. Johnson., Quelques aspects d'éthologie de *Sitophilus zeamais* Motschulsky, 1855 (Coleoptera : Curculionidae), principal prédateur des stocks de riz et de maïs dans la région de Bouaflé, Côte d'Ivoire : lutte par des substances naturelles et stratégies de conservation durable. Thèse de Doctorat Université de Cocody, 2009, 193 p.

[20] F. Johnson, Effets de poudres et d'extraits de 4 variétés de plantes (*Ocimum canum*, *O. gratissimum*, *Mentha sp* (tige jaune), *Mentha sp* (tige violette)) sur quelques paramètres biologiques de *Callosobruchus maculatus*, en laboratoire. Mémoire de DEA Université Cocody, Abidjan, 2001, 64 p.

[21] R. A. Boxall, A critical review of the methodology for assessing farm level grain losses after harvest. Report of the Tropical development and Research Institute, 1986 139p.

[22] CTA, Étude de cas sur les systèmes de connaissances post-récolte dans les Pays ACP, 2015, 5p. Available :

- http://knowledge.cta.int/fr/content/download/34880/472879/file/K4D_CTA_Etude+de+cas_post-recolte.pdf
- [23] H. Affognon, D. Kossou, et A. Bell, Développement participatif de technologie de protection intégrée du maïs dans les greniers en zone rurale au Bénin. GTZ-projet, Eschborn, Allemagne, 1998, 9 p.
- [24] A. Ratnadass, Dynamique des populations d'insectes ravageurs des stocks des céréales en milieux villageois d'Afrique tropicale. Thèse Docteur-Ingénieur en Sciences agronomiques. Institut National Agronomique Paris-Grignon, 1987, 115 p.
- [25] H. Stéphane, Méthode d'utilisation du neem pour la protection du riz contre *Sinophiles sp.* Mémoire de fin de formation en Agronomie. Univ. Bénin, 1993.
- [26] A. Agbaka, Etude biologique et possibilité de lutte contre *Prostephanus truncatus* (HORN) (Coleoptera : Curculionidae) ravageur des stocks de maïs dans les milieux paysans en république du Bénin. Thèse de Doctorat 3^e cycle Université de Cocody, 1996, 145 p.

AUTHORS' PROFILES

Dr JOHNSON Félicia

Ph.D., Assistant Professor, Lecturer and Researcher at the Laboratory of Zoology and Animal Biology, UFR-Biosciences, Félix Houphouët-Boigny University, Côte d'Ivoire. Research focus: *Entomology, crops protection*

Dr OUALI-N'GORAN San-Whouly Mauricette

Ph.D., Associate Professor, Lecturer and Researcher at the Laboratory of Zoology and Animal Biology, UFR-Biosciences, Félix Houphouët-Boigny University, Côte d'Ivoire. Research focus: *Entomology, crops protection*

Dr BOGA Jean-Pierre

Ph.D., Associate Professor, Lecturer and Researcher at the Laboratory of Zoology and Animal Biology, UFR-Biosciences, Félix Houphouët-Boigny University, Côte d'Ivoire. Research focus: *Entomology, Termitology*

Dr TANO Yao

Ph.D., Professor, Lecturer and Researcher at the Laboratory of Zoology and Animal Biology, UFR-Biosciences, Félix Houphouët-Boigny University, Côte d'Ivoire. Research focus: *Entomology, Termitology*

Dr FOUA-BI Kouahou

Ph.D., Professor, Lecturer and Researcher at the Laboratory of Zoology and Animal Biology, UFR-Biosciences, Félix Houphouët-Boigny University, Côte d'Ivoire. Research focus: *crops protection*.