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Efficacy of *Cymbopogon Schoenanthus* L. Spreng (Poaceae) Extracts on Diamondback Moth Damaging Cabbage

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Abstract

This study aims to examine the insecticidal properties of the aerial part of *Cymbopogon schoenanthus*. Cabbage plants were sprayed with the aqueous extracts of *C. schoenanthus* leaves as treatment, and the damage levels of *Plutella xylostella* was assessed. *In vitro*, the emulsified essential oil concentrations were used in a contact test on the larvae in order to assess the mortality effects. The larvae survival time was only 22 seconds with *C. schoenanthus* emulsified oil treatment (2 g/l), whilst it exceeded 44,100 seconds (over 12 hours) for the dimethoate. The nutrition test showed that at 48 h period, a significant effectiveness against larvae was observed with emulsified oil treatment 2 g/l (60% mortality) versus 10% of mortality for dimethoate. *Cymbopogon schoenanthus* can validly be used as alternative in *P. xylostella* management. The results of the field experiments showed no significant difference between the treatments and the control in terms of marketable cabbages harvested.

Keywords: Cabbage; *Plutella xylostella*; *Cymbopogon schoenanthus*; Lomé

Introduction

Apart from being consumed as a current vegetable, cabbage has been valued for medicinal purposes in treating headaches, gout, and diarrhea, inflammatory and gastrointestinal disorders [1-4]. Some researchers have focused their works on the capacity of cabbage to reduce the risks of some cancers [5,6], especially due to the content of glucosinolates and derived products, flavonoids and other phenolics in cabbage [7-9]. The antioxidant activity of these compounds has been shown to correlate with vitamin C and phenolic phytochemicals content [4,6,10,11].

The intensified growing of cabbage has led to a common problem of high pest infestation, which is caused mostly by the Diamondback Moth (DBM) *Plutella xylostella* [12-14]. DBM larvae are very difficult pests to control [15] and therefore, are the greatest threat to crucifer production in many parts of the world. The losses can reach the 90% [13,16]. This explains the large use of insecticides in crucifer production. Owing to its polyvoltine characteristics and serious overlap of generations, this pest can easily develop resistance to various kinds of insecticides [17-19], including biological one such as *Bacillus thuringiensis* [20-22], and particularly in sub-tropical and tropical countries [23]. To overcome resistance, farmers resort to increasing frequency and rates of pesticide applications and to mixed cocktails of pesticides [16]. In addition, the information about the chemical composition of these pesticides is not always publicly available [24]. In Togo, vegetable producers currently apply seven different chemical insecticides (fipronil, chlorpyrifos ethyl, cypermethrin, dimethoate, endosulfan, *Bacillus thurgensis* and acephate) on cabbage and in over 11 applications within 3 months of crop growth prior to harvest. Indiscriminate use of pesticides constitutes one of the main environmental and public health problems in developing countries leading to harmful effects on the ecosystems, the health of both farmers and consumers [25-29].

Biological options in an integrated pest management (IPM) approach offer a solution to sustainable control of DBM. In West Africa, farmers use botanical pesticides, such as plants extracts of *Azadirachta indica* A. Juss, *Melia azedarach* L. against DBM [30]. *Cymbopogon schoenanthus* is efficient in the biological control against pests [31,32]. *Cymbopogon schoenanthus* L. Spreng. (Poaceae) or lemon grass, originally from India, is a warm climate aromatic plant that grows in Togo [31]. It's essential oils are very rich in piperitone [31,33,34] which is responsible for the insecticidal activity of this plant [31,35]. This present work aims at using aqueous leaf extracts and low concentrations of essential oil of *C. schoenanthus* as an integrated management approach to the control populations of *P. xylostella* and their larvae *in vitro* and the field.

Materials and Methods

Experimental site

Experiments were conducted from May 2009 to August 2010 at Agricultural Teaching Experimental Station (ATES) of University of Lomé (UL), Togo. Plant extractions, nutrition and contact tests on *P. xylostella* were carried out respectively in Chemistry and Plant Biology laboratories of the *Ecole Supérieured'Agronomie* (ESA) of UL.

Plant and materials

Cabbage cultivar "KK cross" purchased in a seeds shop in the outskirts of Lomé was used for the assay. Leaves of *C. schoenanthus* were collected at the Agricultural Teaching Experiment Station of UL where this plant was cultivated just for experimental purposes.

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Source of insects

Fourth instars larvae of *P. xylotella* were collected in cabbage growing field and from a small rearing unit of *P. xylostella* of ATES.

Chemical insecticide dimethoate was purchased from a local supplier as 'Calidim' 400 EC (Caliope Chemical Industries Ltd, France).

P. xyllostella larvae control with emulsified oil of *C. schoenanthus in vitro*

Contact tests: Ten fourth instars larvae were introduced into a Petri dish, and were sprayed (using ULV apparatus) with the five formulations: DW (Distilled water); THE1 (essential oil 2 g, hand soap containing soda 2 g, distilled water 96 g); THE2 (essential oil 1 g, hand soap containing soda 2 g, distilled water 97 g); SW (hand soap containing soda 2 g, distilled water 98 g); and DT (40 µl aqueous solution containing 0.25 mg of active ingredient). The soap is an adjuvant used to support oils on the leaf surface and during larvae contact. The test was replicated four times with each formulation. Larval behavior was observed with a magnifying glass, and a chronometer was used to determine the duration of larval survival. The parameter measured was mortality, and larvae were considered dead if they did not move either their head or their thorax when touched.

Nutrition test: A randomized complete block design five treatments each replicated 4 times was used. Fresh cabbage leaves discs (diameter 5 cm) were sprayed with the formulations DW, THE1, THE2, SW and DT and then placed in Petri dishes. Ten fourth instar larvae were introduced into each Petri dish. The development of the larvae feeding on sprayed leaves discs was observed at 24, 48, 72 and 96 hours. Three parameters were recorded: mortality, larval stage and adult emergence.

Aqueous extracts preparation: Aqueous extracts of *Cymbopogon schoenanthus* leaves were obtained according to the following methodology: 1) three years old leaves were harvested, chopped to fine particles size and shade dried at room temperature for four days; 2) three formulations, TS50, TS100, TS150, were obtained with 50 g, 100 g and 150 g respectively of chopped dried leaves infused in one liter of water for 24 hours.

Effects of *C. schoenanthus* leaves aqueous extracts on the field: In our investigation, different concentrations of aqueous extracts of *C. schoenanthus* leaves were used as an integrated management approach to the control of *P. xylostella* under field conditions. An untreated small plot of cabbage was placed about 15 m from the test plots to serve as a control. After one month in seedbed, the seedlings were transplanted to the plots. Plot size was 3.50 m × 1.20 m each, with a spacing of 75 cm between plants and 60 cm between rows, to create two rows of 5 plants each. Spacing between plots and replications were 1.5 m and 1.5 m, respectively. Before the planting, 30 kg of organic manure collected from extensive poultry farming was applied to each plot. The seedlings were sprinkled with water two times per day. No insecticide was used in the seedbed, but after the planting, the organophosphorus insecticide dimethoate was used weekly at 400 g of active ingredient per hectare (the dose indicated by manufacturer) to control DBM on every plot until the pre-heading stage. After this phase, three doses of *C. schoenanthus* aqueous extracts (TS50: 50 g/l, TS100: 100 g/L and TS150: 150 g/L) were applied weekly at a rate of 6 liters for the 4 plots during 4 weeks. One liter of dimethoate prepared solution was used for 4 plots, and the treatment was stopped 15 days before harvest to respect persistence time. Sprays were applied with a manually operated knapsack sprayer at 1.5 liter per treatment. A randomized complete block design (RCBD) with four treatments replicated four times was used. At harvest, variables recorded for analysis were the yield, the circumference, the weight of the heads. For damage analysis, the cabbage leaves were classified according to the level of the perforations caused by the larvae (Table 1).

Statistical analysis

Significant differences among data concerning cabbage head circumference, weight, yield, level of damage, and *P. xylostella* larval mortality and adult eclosion were determined with analysis of variance using Systat 5.0 software. Pairwise comparisons were done using the Fisher LSD at $p < 0.05$. All data are presented as means ± standard deviation.

Results

Toxicity of *C. schoenanthus* oil to *P. xylostella* larvae (contact test)

The formulations THE1 and THE2 of *C. schoenanthus* emulsified oil caused a faster mortality of the larvae than dimethoate suspension. The mean survival times in a group of 10 larvae were 22, 33 and 44100 seconds respectively for THE1, THE2 and dimethoate (Table 2). Larvae mortality time was significantly lower in the *C. schoenanthus* emulsified oil treatment compared to the control dimethoate (ANOVA: $F_{0.05(4)}$=333.73; P<0.001). Thus *C. schoenanthus* emulsified oil acts more quickly than synthetic insecticide used in the present study. Larvae treated with the soap preparation (SW) survived for 330 seconds.

Nutrition Test

The results in Table 3 showed that different concentration of pesticide tested affected differently the instars of *P. xylostella* larvae. Feeding damage was observed on the leaf discs after 24 hours indicating that the larvae fed on the leaves. Generally, THE2, SW and DT treatments caused similar death rates, which ranged from 5-12.5%. This value turned around 10%. These formulations did not differ significantly from each other. However, larval mortalities were 25% and 60%, respectively, at 24 h and over 48 h for THE1. A significant effectiveness against larvae of *P. xylostella* was observed when cabbage leaves were treated with THE1 dose (ANOVA: $F_{0.05(4)}$=26.25; P<0.001).

Scale	Perforations caused by the larvae (damage)
Degree 0	No damage
Degree 1	The first external leaves of the head: 1% of the leaves perforated
Degree 2	2 - 5% of the leaves perforated
Degree 3	6 - 10% of the leaves perforated, but the head is not damaged
Degree 4	11 - 30% of the leaves perforated with minor damage on the head
Degree 5	More than 30% of the leaves perforated and head damaged with presence of holes and waste resulting from the metabolism of the larvae.

Table 1: Classification of cabbage leaves damaged.

Insecticides	THE1	THE2	SW	DT	DW
Mean Survival	22.5	33.2	330.0	44100	86400
Time (sec)	±4.9*	± 6.3*	± 77.4	± 9467.8	± 0.0

Larvae were sprayed with DT, SW, DW and the essential oil of *C. schoenanthus* at 2 doses (THE1 and THE2). Data are Means ± SD. *P < 0.05 (THE1 and THE2 vs DT). DW: distilled water; THE1: essential oil 2g + hand soap containing soda 2 g + distilled water 96 g; THE2: essential oil 1 g + hand soap containing soda 2 g + distilled water 97 g SW: hand soap containing soda 2 g + distilled water 98 g; DT: 40 µl aqueous solution containing 0.25 mg of active ingredient.

Table 2: Mean survival time of the larvae of *P. xylostella* after treatment with emulsified oil of *C. schoenanthus* (100% mortality).

As in the contact or feeding tests, the formulation THE1 appeared more effective. Figure 1 reports percentage of *P. xylostella* adult eclosion at 96 hours. Concerning the absolute control by the DW and THE2 treatments, 95% and 65% adults, respectively, have evolved. THE1 (7.5%) significantly (ANOVA: $F_{0.05(4)}$=9.5; P<0.005) prevented the adult evolution than DW, SW and THE2. The adult eclosion rate recorded with dimethoate was 37.5%.

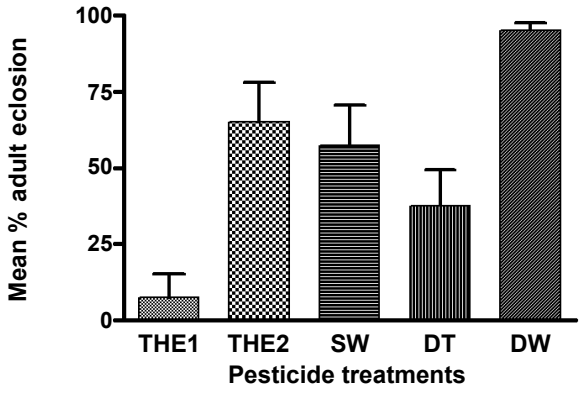
Harvest Data

Overall, insect populations were low. Generally, it was observed that the cabbage plants thrived well, and all the harvested heads of cabbage from each treatment plot were marketable. First attacks began at pre-heading stage, and an ave rage of 3-5 larvae were recorded per 10 plants. By comparing the various treatments at the harvest period, a strong presence of larvae (more than 4 larvae per 10 plants) was observed on certain heads harvested from the dimethoate-treated plot. However, the heads treated with dimethoate were slightly larger than those treated with the botanical aqueous extracts: 61.70 ± 3.71 cm versus 59.85 ± 5.86 cm; 59.53 ± 1.96 cm and 60.32 ± 2.86 cm for TS50, TS100 and TS150 respectively. The head weight also showed a slight difference between the dimethoate treatment and the botanical extracts: 1.69 ± 0.32 kg versus 1.41 ± 0.36; 1.57 ± 0.31 kg and 1.56 ± 0.19 kg for TS50, TS100 and TS150, respectively (Table 4). There were no statistically significant differences between the dimethoate and *C. schoenanthus* aqueous extract treatments (ANOVA: $F_{0.05(3)}$=0.38; P>0.7). The yield was slightly higher and the level of damage concerning the heads harvested from control plot (dimethoate treatment) was relatively of low quality compared to the treatments the aqueous extracts the botanical aqueous extracts (4.22 ± 0.34 kg/m² and 2.30 ± 0.14 versus 3.45 ± 0.40 to 3.93 ± 0.28 kg/m² and 1.80 ± 0.72 to 2.22 ± 0.73 respectively). The ANOVA test for yield and damage parameters showed also no significant difference between the insecticide and the botanical treatment (ANOVA: $F_{0.05(3)}$=0.84; P>0.4).

Larvae mortality induced by insecticides				
Insecticides	**24 h**	**48 h**	**72 h**	**96 h**
THE1	25.0±6*	60.0±5**	60.0±5**	60.0±5**
THE2	10.0±6	12.5±2	12.5±2	12.5±2
SW	5.0±2	10.0±4	10.0±4	10.0±4
DT	10.0±4	10.0±4	10.0±4	10.0±4
DW	0.0±0	7.5±4	7.5±4	10.0±4

Larvae were nourished with fresh cabbage leaves treated with formulations DT, SW, DW and the essential oil of *C. schoenanthus* at 2 doses (THE1 and THE2). Data in percent are Means ± SD. *P < 0.05 (THE1 vs DT); **P < 0.05 (THE1 vs DT). DW: distilled water; THE1: essential oil 2g + hand soap containing soda 2 g + distilled water 96 g; THE2: essential oil 1 g + hand soap containing soda 2 g + distilled water 97 g SW: hand soap containing soda 2 g + distilled water 98 g; DT: 40 µl aqueous solution containing 0.25 mg of active ingredient.

Table 3: Mean percentage of larvae mortalities induced by the insecticides and larvae developing to pupal stage.



Larvae were nourished with fresh cabbage leaves treated with formulations DT, SW, DW and the essential oil of C. schoenanthus at 2 doses (THE1 and THE2). Data in percent are Means ± SD. *P < 0.05 (SW vs DW). **P < 0.05 (THE1 and DT vs DW).
DW: distilled water; THE1: essential oil 2g + hand soap containing soda 2 g + distilled water 96 g; THE2: essential oil 1 g + hand soap containing soda 2 g + distilled water 97 g;
SW: hand soap containing soda 2 g + distilled water 98 g; DT: 40 µl aqueous solution containing 0.25 mg of active ingredient.

Figure1: Evolution of the larvae of P. xylostella towards the adult forms at 96 hours.

Insecticide	Head circum- ference (cm)	Head weight (Kg)	Yield (Kg/m²)	Level of damage
DT	61.70±3.71	1.69±0.32	4.22±0.34	2.30±0.14
TS50	59.85±5.86	1.41±0.36	3.45±0.40	1.80±0.72
TS100	60.32±2.86	1.57±0.21	3.93±0.28	2.22±0.73
TS150	59.53±1.96	1.56±0.19	3.75±0.23	2.15±0.29

Cabbage plants were sprayed weekly with DT and *C. schoenanthus* aqueous extracts at 3 doses (TS50, TS100 and TS150). Measurement was made on ten samples in each case. Data are Means ± SD and non significant (*P*>0.05). DT: Dimethoate treatment (400 g of active ingredient per hectare); TS50: *C. schoenanthus* aqueous extracts treatment (50g/l); TS100: *C. schoenanthus* aqueous extracts treatment (100g/l); TS150: *C. schoenanthus* aqueous extracts treatment (150g/l).

Table 4: Effects of aqueous extracts of *C. schoenanthus* and dimethoate on cabbage Yield and quality.

Discussion

The objective of this study was to investigate the activities of aqueous leaves extracts and low concentrations of essential oil of *C. schoenanthus* to control populations of *P. xylostella* and their larvae. The aqueous leaf extracts of this plant were quite effective against *P. xylostella*, and achieved the similar protection of cabbage to dimethoate. The results of our investigation confirm the reports of Idrissou [36] which revealed that both *Azadirachta indica* and *C. schoenanthus* extracts had equivalent efficiency against DBM of cruciferous plants. The observations showed that the essential oils of *C. schoenanthus* can cause effective mortality of *P. xylostella* larvae. The essential oil extracted from *C. schoenanthus* contained a high percentage of monoterpenes. Studies carried out in Togo showed that the major component of *C. schoenanthus* extract was piperitone with a value bordering 70% [37,33], and was responsible for the insecticidal activity [35]. This component, isolated and purified by Author's name [38], had strong insecticidal activity against eggs, neonate larvae and adults of *Callosobruchus maculatus* at very low concentrations [31]. These observations corroborates the low concentrations of the formulation THE1 (2 g/l) effective effect on larvae of *P. xylostella* in our study. This formulation would ensure a good protection of cabbage against DBM. It can validly used as alternative in *P. xylostella* management.

References

1. de Sousa EMBD, Câmara APC, Costa WA, Costa ACJ, Oliveira HNM et al. (2005) Evaluation of the Extraction Process of the Essential Oil from *Cymbopogon schoenanthus* with Pressurized Carbon Dioxide. Braz. Arch. Biol. Technol. 48: 231-236.

2. Singh J, Upadhyay AK, Bahadur A, Singh B, Singh KP et al. (2006) Antioxidant phytochemicals in cabbage (*Brassica oleracea* L. var. *capitata*). Scientia Horticulturae 108: 233-237.

3. McDougall GJ, Fyffe S, Dobson P, Stewart D (2007) Anthocyanins from red

cabbage-stability to simulated gastrointestinal digestion. Phytochemistry 68: 1285-1294.

4. Samec D, Piljac-Zegaraca J, Bogovic M, Habjanic K, Gruz J (2011) Antioxidant potency of white (*Brassica oleracea* L. var. *capitata*) and Chinese (*Brassica rapa* L. var. *pekinensis* (Lour.)) cabbage: The influence of development stage, cultivar choice and seed selection. Scientia Horticulturae 128: 78-83.

5. Fowke JH, Longcope C, Hebert JR (2000) Brassica Vegetable Consumption Shifts Estrogen Metabolism in Healthy Postmenopausal Women. Cancer Epidemiology, Biomarkers & Prevention 9: 773-779.

6. Tanongkankit Y, Chiewchan N, Devahastin S (2011) Evolution of anticarcinogenic substance in dietary fibre powder from cabbage outer leaves during drying. Food Chemistry 127: 67-73.

7. Vrchovska V, Sousa C, Valentao P, Ferreres F, Pereira JA et al. (2006) Antioxidative properties of tronchuda cabbage (*Brassica oleracea* L. var. costata DC) external leaves against DPPH, superoxide radical, hydroxyl radical and hypochlorous acid. Food Chemistry 98: 416-425.

8. Heo HJ and Lee CY (2006) Phenolic phytochemicals in cabbage inhibit amyloid β protein induced neurotoxicity. LWT - Food Science and Technology 39: 331-337.

9. Volden J, Borge GIA, Bengtsson GB, Hansen M, Thygesen IE et al. (2008) Effect of thermal treatment on glucosinolates and antioxidant-related parameters in red cabbage (*Brassica oleracea* L. ssp. *capitata* f. *rubra*). Food Chemistry 109: 595-605.

10. Nilnakara S, Chiewchan N, Devahastin S (2009) Production of antioxidant dietary fibre powder from cabbage outer leaves. Food and Bioproducts Processing 87: 301-307.

11. Hounsome N, Hounsome B, Tomosc D, Edwards-Jones G (2009) Changes in antioxidant compounds in white cabbage during winter storage. Postharvest Biology and Technology 52: 173-179.

12. Ester A, de Putter H, van Bilsen JGPM (2003) Filmcoating the seed of cabbage (*Brassica oleracea* L. convar.*capitata* L.) and cauliflower (*Brassica oleracea* L.var. *botrytis* L.) with imidacloprid and spinosad to control insect pests. Crop Protection 22: 761-768.

13. Mazlan N, Mumford J (2005) Insecticide use in cabbage pest management in the Cameron Highlands, Malaysia. Crop Protection 24: 31-39

14. Ayalew G (2006) Comparison of yield loss on cabbage from Diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae) using two insecticides. Crop Protection 25: 915-919.

15. Sayyed AH, Saeed S, Noor-Ul-Ane M, Crickmore N (2008) Genetic, Biochemical, and Physiological Characterization of Spinosad Resistance in *Plutella xylostella* (Lepidoptera: Plutellidae). J Econ Entomol 101: 1658-1666.

16. Macharia I, Löhr B, De Groote H (2005) Assessing the potential impact of biological control of *Plutella xylostella* (diamondback moth) in cabbage production in Kenya. Crop Protection 24: 981-989

17. Diaz-Gomez O, Rodriguez JC, Shelton AM, Lagunes-T A, Bujanos MR (2000) Susceptibility of *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) Populations in Mexico to Commercial Formulations of *Bacillus Thuringiensis*. J Econ Entomol 93: 963-970.

18. Xu J, Shelton AM, Cheng X (2001) Comparison of Diadegma insulare (Hymenoptera: Ichneumonidae) and *Microplitis plutellae* (Hymenoptera: Braconidae) as Biological Control Agents of *Plutella xylostella* (Lepidoptera: Plutellidae): Field Parasitism, Insecticide Susceptibility, and Host-Searching. Journal of Economic Entomology 94:14-20.

19. Qian L, Cao G, Song J, Yin Q, Han Z (2008) Biochemical mechanisms conferring cross-resistance between tebufenozide and abamectin in *Plutella xylostella*. Pesticide Biochemistry and Physiology 91: 175-179.

20. Ferré J, Real MD, Rie JV, Jansens S, Peferoen M (1991) Resistance to the *Bacillus thuringiensis* bioinsecticide in a field population of *Plutella xylostella* is due to a change in a midgut membrane receptor. Proc Natl Acad Sci USA 88: 5119-5123.

21. Masson L, Mazza A, Brousseau R, Tabashinik B. (1995) Kinetics of *Bacillus thuringiensis* Toxin Binding with Brush Border Membrane Vesicles from Susceptible and Resistant Larvae of *Plutella xylostella*. J Biol Chem 270: 11887-11896.

22. Soufbaf M, Fathipour Y, Karimzadeh J, Zalucki MP (2010) Bottom-Up Effect of Different Host Plants on *Plutella xylostella* (Lepidoptera: Plutellidae): A Life-Table Study on Canola. Journal of Economic Entomology 103: 2019-2027.

23. Schroer S, Ehlers RU (2005) Foliar application of the entomopathogenic nematode Steinernema carpocapsae for biological control of diamondback moth larvae (*Plutella xylostella*). Biological Control 33: 81-86.

24. Ng PJ, Fleet GH, Heard GM (2005) Pesticides as a source of microbial contamination of salad vegetables. International Journal of Food Microbiology 101: 237-250.

25. Ciglasch H, Busche J, Amelung W, Totrakool S, Kaupenjohann M (2008) Field Aging of Insecticides after Repeated Application to a Northern Thailand Ultisol. J Agric Food Chem 56: 9555-9562.

26. van der Werf HMG (1996) Assessing the impact of pesticides on the environment. Agriculture Ecosystems and Environment 60: 81-96.

27. Barnard C, Daberkow S, Padgitt M, Smith ME, Uri ND (1997) Alternative measures of pesticide use. The Science of the Total Environment 203: 229-244

28. Isin S, Yildirim I (2007) Fruit-growers' perceptions on the harmful effects of pesticides and their reflection on practices: The case of Kemalpasa, Turkey. Crop Protection 26: 917-922.

29. Waichman AV, Eve E, da Silva Nina NC (2007) Do farmers understand the information displayed on pesticide product labels? A key question to reduce pesticides exposure and risk of poisoning in the Brazilian Amazon. Crop Protection 26: 576-583.

30. Godonou I, James B, Atcha-Ahowé C, Vodouhè S, Kooyman C et al. (2009) Potential of Beauveria bassiana and Metarhizium anisopliae isolates from Benin to control *Plutella xylostella* L. (Lepidoptera: Plutellidae). Crop Protection 28: 220-224.

31. Ketoh GK, Koumaglo HK, Glitho IA (2005) Inhibition of *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) development with essential oil extracted from *Cymbopogon schoenanthus* L. Spreng. (Poaceae), and the wasp *Dinarmus basalis* (Rondani) (Hymenoptera: Pteromalidae). Journal of Stored Products Research 41: 363-371.

32. Ketoh GK, Koumaglo HK, Glitho IA, Huignard J (2006) Comparative effects of *Cymbopogon schoenanthus* essential oil and piperitone on *Callosobruchus maculatus* development. Fitoterapia 77: 506-510.

33. Koba K, Sanda K, Raynaud C, Nenonene YA, Millet J, et al. (2004) Activités antimicrobiennes d'huiles essentielles de trois *Cymbopogon* sp. africains vis-à-vis degermes pathogènes d'animaux de compagnie. Ann Méd Vét 148: 202-206.

34. Khadri A, Serralheiro MLM, Nogueira JMF, Neffati M, Smiti S, et al. (2008) Antioxidant and antiacetylcholinesterase activities of essential oils from *Cymbopogon schoenanthus* L. Spreng. Determination of chemical composition by GC–mass spectrometry and ^{13}C NMR. Food Chemistry 109: 630-637.

35. Kullenberg J (1951) Traité de zoologie des insectes. Tome 10 Fascicule 2: 31- 40.

36. Idrissou N (2003) Etude de l'efficacité de l'extrait aqueux de *Cymbopogon schoenanthus* Treng. Contre la teigne des crucifères *Plutella xylostella* L. (Lepideptora: Hyponomeutidae). Mémoire d'Ingénieur Agronome, Ecole Supérieure d'Agronomie, Université de Lomé. 63p.

37. Ketoh GK, Glitho IA, Huignard J (2002) Susceptibility of the bruchid *Callosobruchus maculatus* (Coleoptera: Bruchidae) and its parasitoid *Dinarmus basilis* (Hemenoptera: Pteromalidae) to three essential oils. Journal of Economic Entomology 95: 174-182.

38. Ketoh GK, Glitho IA, Koumaglo KH and Garneau FX (2000) Evaluation of essential oils from six aromatic plants in Togo for *Callosobruchus maculatus* F. pest Control Insect Science and its Application 20: 45-49.