

Title: Entomocidal activity of four leaves powders against: *Sitophilus zeamais* (L.) on stored maize and *Callosobruchus maculatus* (F.) on stored cowpea.

Dieudonné A. KPOVIESSI^{1*}, Aimé H. BOKONON-GANTA¹, Daniel C.

CHOUGOUROU²

¹ Laboratoire d'Entomologie Agricole (LEAg), Faculté des Sciences Agronomiques, Université d'Abomey-Calavi (FSA/UAC) - 01 BP 526 Cotonou, République du Bénin.

² Laboratoire de Recherche et d'Etude en Biologie Appliquée (LARBA), Département de Génie de l'Environnement, Ecole Polytechnique d'Abomey-Calavi, Université d'Abomey-Calavi (EPAC/UAC) - B.P. 2009 Cotonou, République du Bénin.

*Corresponding author; E-mail: akpoviessi@gmail.com; kakovognon@yahoo.com; Tel: (+229) 96 23 41 16 / (+229) 95 08 10 07

Abstract

The major problem of food security in rural area is to reduce significantly the post-harvest losses essentially due to the insects' pests. At the sight of treatments costs and especially the various damages of synthetics insecticides, news inexpensive tools quite safe repellents and antifeedants for insects, and available for small-scale farmers must be found. In this study, entomocidal activity of four leaves powders was tested against *Sitophilus zeamais* and *Callosobruchus maculatus* on stored products. PROTECT DP® insecticide was applied at recommended dose; 5g of each leaves powders were tested for 50g of crops seeds (*Zea mays*, *Vigna unguiculata*). Twenty (20) individuals at 24h old of each insect's species were introduced into each jar. The jars were covered with linen cloth and were kept outdoors during forty-five days (45) using randomized block design with four replicates. Moreover, mortality rate and F1 progeny of insects were recorded; percentages of weight loss, seeds damaged and seeds germinated were also assessed. Results obtained showed that PROTECT DP® insecticide and leaves powders used had caused significant mortality rate and allowed having high germination rate compared to the control (untreated). The percentage of weight loss and seeds damaged were significantly reduced with leaves powders compared to the control. According to F1 progeny, *V. amygdalina* and *E. citriodora* leaves powders reduced to 2.00 ± 0.91 insects and 21.25 ± 4.15 insects respectively for *C. maculatus* and for *S. zeamais*, while the control allowed having the greatest number for both cases, with 86.00 ± 13.88 insects

and 164.50 ± 4.40 insects respectively for *C. maculatus* and *S. zeamais*. Results showed some entomocidals activities of four leaves powders used. These findings suggest that the tested leaves powders can be used as bioinsecticides for control of *C. maculatus* and *S. zeamais* pests of stored products.

Keys words: *Sitophilus zeamais*, *Callosobruchus maculatus*, maize, cowpea, leaves powders, post-harvest, food security.

Introduction

Traditionally, the plants and minerals used as protectants of stored products is an old practice used throughout the world (Golob and Webley, 1980). With the advent of synthetic insecticides in this latest century, these traditions have been largely neglected by producers. Certain authors have shown that repercussions of the use of chemical insecticides include sudden deaths, blindness, skin irritation and pest resurgence in the ecosystem (Lowenberg-DeBoer and Ibro, 2008; Omoloye, 2008). Thus, the insects' resistances development, killing of non-target species, pollution of environment, toxic residue, increasing costs are recorded as environmental repercussion of abuse and misuse of chemicals insecticides (Akunne and Okonkwo, 2006; Ofuya *et al.*, 2008). However the potential hazards for consumers and for animals from synthetics molecules, the increase of insect resistance to the synthetic insecticides and the destruction of environment have led to search others news methods, having lower dangers for consumers, animals, and lower persistence in the environment, to protect some cultures from insects (Kpoviessi *et al.*, 2017b; Ngamo, 2004; Regnault and Hamraoui, 1997).

Several researches have been conducted on the use of natural products, especially on plant extracts having insecticidal properties and whose undesirable effects have not been reported in humans (Isman, 2000). Thus the essential oils extracted from plants have been widely used in the fight against pests of grain in storage (Nerio *et al.*, 2010; Regnault and Hamraoui, 1997; Tapondjou *et al.*, 2002; Tapondjou *et al.*, 2003). The insecticidal properties of plants products, their nematicide, larvicide, ovicidal, sterilizing, repulsive and anti-feeding effects have made several studies (Kosma *et al.*, 2011; Kouninki, 2007; Ndomo *et al.*, 2009; Ngamo and Hance, 2007). The uses of plants products or minerals to protect the storage against post-harvest insects have been shown by several studies. Thus, (Tapondjou *et al.*, 2003) have shown the bioefficacy of powders and essential oils from leaves of *Chenopodium*

ambrosioides and *Eucalyptus saligna* to the cowpea bruchid, *Callosobruchus maculatus*. The powders and essential oils from both plants were found to have insecticidal and repellent properties against *C. maculatus*. Those derived from the leaves of *C. ambrosioides* have been more toxic (DL50 = 2.8 g/kg for powder and 0.17 μ L/g grains for essential oil) than those of *E. saligna* (DL 50 = 322 g/kg for powder and 0.19 μ L/g grains for essential oil) in treated grains.

(Akunne *et al.*, 2013), have studied the efficacy of mixed leaf powders of *Vernonia amygdalina* (L.) and *Azadirachta indica* (A. Juss) against *Callosobruchus maculatus*. It was found the mixed powder from both plants caused mortality, during the exposure period. And (Kpoviessi *et al.*, 2017a) have also shown the bioefficacy of powdery formulations based on kaolin powder and cashew (*Anacardium occidentale* L.) balms to control *Callosobruchus maculatus* in stored cowpea (*Vigna unguiculata* L.). In this study authors have shown that formulated powders caused a significant mortality rate and improved the germination rate of seeds, then, F1 progeny decreased with increased dose, (25.50 \pm 7.96 insects to 44.50 \pm 7.67 insects for 0.5 g; and 11.25 \pm 4.62 insects to 29.50 \pm 3.22 insects for 1 g).

Nowadays, cereals occupy an important place in the improving of food security in Africa, especially in Benin. In rural area in Benin, the cereals protections are currently based on the use of synthetics insecticides which are responsible of deleterious effects on consumers' health. Cowpea and maize are mains crops always used for staple food in rural area; in field the yields of those crops are under the climate changes effects. In storage these crops are submitted to the post-harvest insects' activities. Indeed, apart from being a staple food, these crops (*Vigna unguiculata* and *Zea mays*) are mains sources of income for many rural households. To protect their crops in storage from insects' damages at lower cost, small-scale farmers have commonly used local plant materials, including seeds powders or leaves powders.

The present experiment was designed to compare the insecticidal potency of some leaves powders against adults *Callosobruchus maculatus* and *Sitophilus zeamais* on cowpea grain and maize grain respectively.

MATERIAL AND METHODS

Rearing of the experimental insects

The insect culture for obtaining insects adults (*Sitophilus zeamais*, *Callosobruchus maculatus*) for this study were carried out using maize seeds and cowpea seeds in a room at temperature from 25 to 27 °C and relative humidity from 70 to 75%. The insects stock used was obtained at the Laboratory of Agricultural Entomology of the University of Abomey-Calavi (Benin). During 7 days, the maize seeds and the cowpea seeds used for the insect culture are sterilized with freezer at -20°C. Indeed, one hundred (100) adults of each insect's species (*S. zeamais*, *C. maculatus*) are used to infest 200 g of maize and cowpea seeds each one contained in jars. The openings of these jars were carefully covered with linen cloth to allow ventilation and prevent the exit of insects and other external contamination. About 72 h after infestation, the previously one hundred 100 adults of each insect's species introduced in jars were retired, and the infested grains are left in incubation until emergence of new adult insects. At emergence, the jars contents were filtered in order to eliminate the emerged adults. After 24 h, the jars contents filtered the day before were filtered again in order to obtain adults of 24 h old used in this experiment.

Sources and preparation of leaves powders

The matured fresh leaves of *Eucalyptus citriodora* and *Psidium guajava* were obtained from the natural vegetation of Faculty of Agronomic Sciences of University of Abomey-Calavi (Benin). The matured fresh leaves of *Vernonia amygdalina* and *Ocimum gratissimum* were obtained from the organics vegetables production center of University of Abomey-Calavi. These plants leaves were then dried in the shade during 5 days at 25 to 27 °C and relative humidity from 70 to 75%. These dried leaves were ground into powder using electric grinder (MODEL: WARING BLINDER 8010 EG). The powders were further sieved to obtain fine powders before being stored in separate jars containers with tight lids and stored in a refrigerator for subsequent use.

Experimental essay

Contact toxicity of leaves powders

The purpose of this part of the experiment was to study the insecticidal activity of the various leaves powders. In order to evaluate the effects of these leaves powders against *Callosobruchus maculatus* on stored cowpea and *Sitophilus zeamais* on stored maize. With the various leaves powders, it was associated a control treatment with seeds merely in the jars (negative control); and another treatment with seeds impregnated of powdery synthetic

insecticide PROTECT DP® (Deltamethrine 1g/kg + Pyrimiphos-methyl 15g/kg) (positive control).

In this experiment, the crops (cowpea seeds and maize seeds), used for the test were conserved with freezer at -20°C to ward off any stage of insect infestation probably in the crops (cowpea or maize). For each test, 50 g of cowpea seeds and maize seeds were introduced into each cylindrical jar (6 cm diameter and 12 cm height). The crops (cowpea seeds, maize seeds) were treated with each type of leaves powders previously established. 5 g of each powder were added separately into the jars holding 50 g of cowpea seeds and maize seeds. The contents were vigorously shaken, and then the tests were repeated 4 times for each treatment (leaves powders treatments, negative control and positive control). The unit was arranged in a randomized block design per crop (cowpea and maize) with 4 repetitions per treatment.

20 insects at 24 h old randomly selected were used to infest content of each jar. The mortality of the insects was counted each day from the beginning of the test to the death of total insects introduced per jar. The openings of these jars were carefully covered with linen cloth to allow good ventilation, a good exchange with ambient conditions and prevent exit of insects and other external contamination. The content of each jar was sieved at 45th day after infestation, the adults insects were collected from the jar and were counted for F1 progeny. The data-collecting was related not only to the biological parameters (the mortality of the insects, F₁ progeny production), but also on the agronomics parameters (the seeds damaged and weight loss at the end of the storage period (formula), and the germination test);

Mortality percentages were corrected using the Abbot formula, (Abbott, 1925) by taking account of the natural mortality observed in the control jars;

$$M_C = \frac{M_o - M_t}{100 - M_t} \times 100$$

With:

M_c = corrected mortality (%),

M_o = the mortality of insects observed in jars treated (%) and,

M_t = the mortality of insects naturally observed in the control jars (%).

The percentages of weight loss were calculated using the following formula:

$$\% \text{ weight loss} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times 100$$

Percentage of seed damaged

The percentage of seed damage was assessed at the end of experiment; the number of damaged cowpea seeds and maize seeds was counted. Seeds with holes, those presenting the damage of attack and wholesome seeds were identified. The percentage of grains damaged was calculated at the 45th day of experiment, using the following formula:

$$\% \text{ Seed damage} = \frac{\text{Number of seeds damaged}}{\text{total number of seeds}} \times 100$$

The germination test

The test of germination was carried out at the end of insect emergence. Indeed, samples of 50 seeds without visible appearance of attack were collected from each treatment to evaluate their germination potency. The Germination test was carried out on absorbing paper by using the method of paper disc described by (Hanson, 1995).

The following formula was used to determine the percentage of germination.

$$\% \text{ Germination} = \frac{\text{Number of grains that germinated}}{\text{Total number of grains planted}} \times 100$$

Data analysis

Statistical analysis was performed using R computer Software package version 2.15.3. Data collected, were subjected to the one-way analysis of variance. In the case of significant difference, Student Newman-Keuls (SNK) test was used to separate means at 5% significant levels. The mortality rates in the treated jars were corrected by the Abbot formula (Abbott, 1925) by taking account the natural mortality rate obtained in the control jars.

Results

Effect of leaves powders on mortality of *C. maculatus* and *S. zeamais*

Table 1: Mean Mortality of *C. maculatus* on Cowpea Seeds and *S. zeamais* on maize seeds

Crop	Treatments	24h	48h	72h	96h	120h	144h
<i>Zea mays</i>	<i>E. citriodora</i>	3.75 ±1.25b	13.75±1.25c	32.50±3.22b	51.18±3.07c	76.34±2.64b	100.00±0.00a
	<i>O. gratissimum</i>	6.25±2.39b	20.00±2.88c	36.25±4.26b	61.51±3.42bc	91.15±2.96a	100.00±0.00a
	<i>P. guajava</i>	5.00 ±2.04b	20.00±3.53c	46.25±4.73b	71.90±4.23b	89.94±4.71a	100.00±0.00a
	<i>V. amygdalina</i>	6.25±2.41b	30.00±4.56b	50.00±10.60b	76.97±9.58b	98.61±1.38a	100.00±0.00a
	control	0.00±0.00b	0.00±0.00d	0.00±0.00c	2.50±1.44d	15.00±2.04c	28.75±1.25b
	Insecticide	100.00±0.00a	100.00±0.00a	100.00±0.00a	100.00±0.00a	100.00±0.00a	100.00±0.00a
<i>Vigna unguiculata</i>	<i>E. citriodora</i>	3.75±1.25b	17.50±1.44b	24.89±2.04c	41.50±2.97d	67.64±4.01c	100.00±0.00a
	<i>O. gratissimum</i>	6.25±2.39b	20.00±2.04b	36.74±3.42b	57.18±4.89c	87.68±4.42b	100.00±0.00a
	<i>P. guajava</i>	5.00±2.04b	16.25±3.14b	23.72±1.64c	40.03±2.49d	66.17±2.98c	100.00±0.00a
	<i>V. amygdalina</i>	6.25±2.39b	22.50±2.50b	44.45±4.55b	71.24±5.01b	98.43±1.56a	100.00±0.00a
	control	0.00±0.00b	0.00±0.00c	5.00±2.04 d	12.50±1.44e	18.75±1.25d	27.50±1.44b
	Insecticide	100.00±0.00a	100.00±0.00a	100.00±0.00a	100.00±0.00a	100.00±0.00a	100.00±0.00a

treated with leaves powders of *V. amygdalina*, *E. citriodora*, *O. gratissimum* and *P. guajava*.

Each value is a mean ± standard error of four replicates. Means (±SE) in each column followed by the same letter are not significantly different ($P>0.05$) using the Student Newman-Keuls (SNK) test.

The effects of the leaves powders on the mortality of insects (*C. maculatus* and *S. zeamais*) are presented in Table 1. The result showed that the means mortality of adults' insects (*C. maculatus* and *S. zeamais*) were higher in the crops seeds (cowpea and maize) treated with leaves powders than those untreated (control). Thus, the results of analysis of variance (ANOVA) showed that all plants powders used had significant difference on mortality of stored product insects ($p<0.001$). At 24h of application, only insecticide powder used had 100.00±0.00% of mortality in relation to others applications on both crops. Within 48h of leaves powders application, all percentages of mean mortality were lower than 50.00% as well for *S. zeamais* on *Zea mays*, as for *C. maculatus* on *Vigna unguiculata*. At 72h of leaves powders application, 50.00±10.60% of *S. zeamais* mortality was reached in the case of *V. amygdalina* leaves powders application on *Zea mays*. In the same time, on *V. unguiculata*, the high mortality of *C. maculatus* was reached with *V. amygdalina* at 44.45±4.55%. All plants powders used at 96h on *Zea mays* infested by *S. zeamais* allowed having at least 50.00% of mortality; at this moment, with *V. unguiculata*, only *O. gratissimum* and *V. amygdalina* allowed having more than 50.00% of mortality with 57.18±4.89% and 71.24±5.01% for *O. gratissimum* and *V. amygdalina* respectively. At 120h of exposure, all the

tested plants powders were able to achieve high percentage of mortality as well for *S. zeamais* on *Zea mays*, as for *C. maculatus* on *Vigna unguiculata*, but none of these tested plants powders was able to achieve complete mortality of both insects at 120h. Meanwhile, for untreated (control) treatment, the percentage of insects' mortality reached $15.00 \pm 2.04\%$ and $18.75 \pm 1.25\%$ for *S. zeamais* and *C. maculatus* respectively. After 144h of exposure all the four tested leaves powders used in this experiment caused $100.00 \pm 0.00\%$ mortality for both tested insects. Indeed, all the tested powders had entomocidal effect on the insects used at 144h of exposure. On the other hand, during the mortality test, *V. amygdalina* leaves powders had most potent on both tested insects, having reached 50.00% of insects' mortality before others leaves powders.

Effect of leaves powders on percentage of weight loss and on percentage of seeds damaged

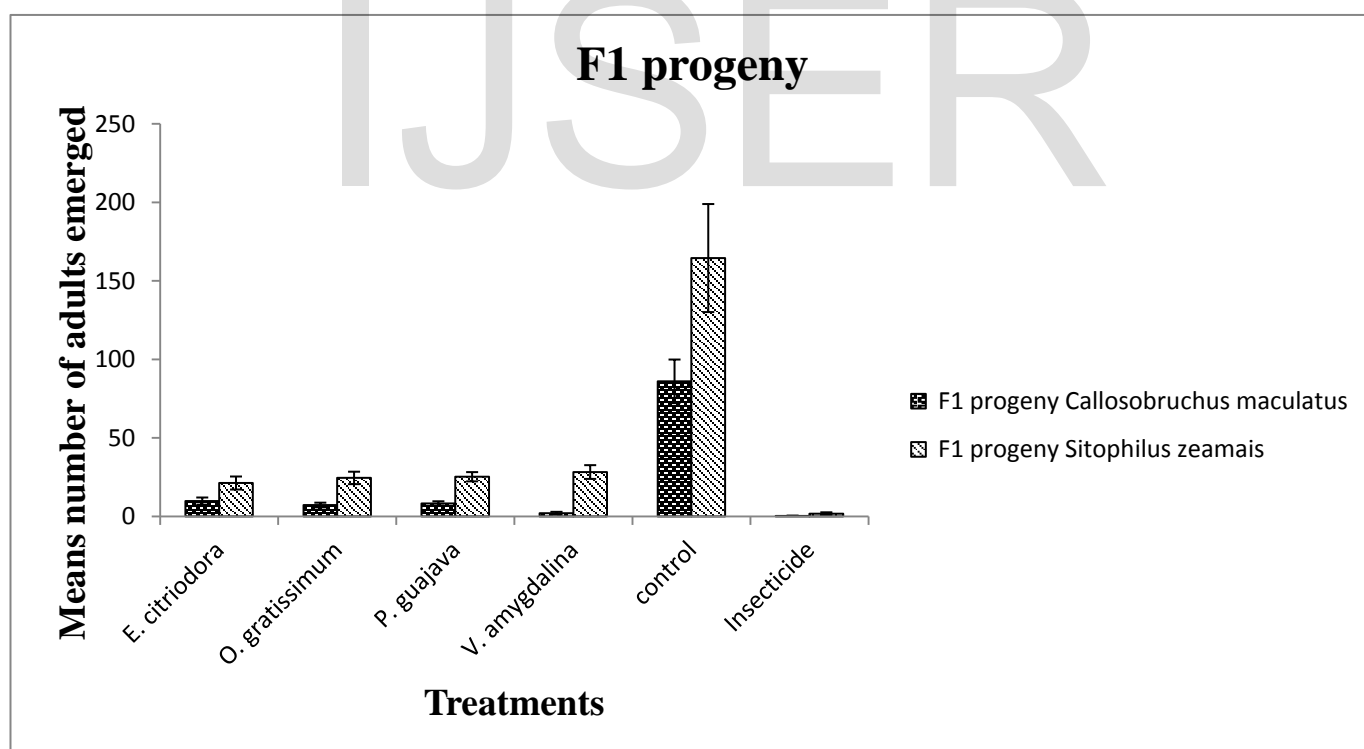
Table 2: Percentage of weight loss, and percentage of seeds damage

Crop	Treatments	% weight loss	% seeds damaged
<i>Zea mays</i>	<i>E. citriodora</i>	5.27 ± 1.18 b	3.85 ± 0.76 b
	<i>O. gratissimum</i>	5.48 ± 1.14 b	3.73 ± 0.17 b
	<i>P. guajava</i>	4.73 ± 1.46 b	3.95 ± 0.78 b
	<i>V. amygdalina</i>	4.49 ± 0.75 b	3.90 ± 0.40 b
	control	31.83 ± 9.70 a	57.03 ± 5.07 a
	Insecticide	2.37 ± 0.52 b	0.26 ± 0.13 b
<i>Vigna unguiculata</i>	<i>E. citriodora</i>	7.03 ± 0.52 b	2.08 ± 0.29 b
	<i>O. gratissimum</i>	3.29 ± 0.92 b	1.67 ± 0.26 b
	<i>P. guajava</i>	6.47 ± 0.27 b	1.77 ± 0.30 b
	<i>V. amygdalina</i>	3.82 ± 0.88 b	0.85 ± 0.13 b
	control	34.45 ± 9.96 a	54.27 ± 4.24 a
	Insecticide	2.60 ± 0.42 b	0.05 ± 0.05 b

Each value is a mean \pm standard error of four replicates. Means (\pm SE) in each column followed by the same letter are not significantly different ($P > 0.05$) using the Student Newman-Keuls (SNK) test.

The Table 2 presents the various effects of leaves powders used on percentage of weight loss, and on percentage of seeds damaged. The results showed that the leaves powders had significant difference on percentage of weight loss and seeds damaged, ($p < 0.001$). All treatments used (insecticide and leaves powders application), had limited the weight loss and seeds damaged. However, insecticide application allowed reducing the weight loss and seeds damaged in the case of both crops (*Zea mays* and *Vigna unguiculata*). For insecticide application, the percentages of weight loss were reduced to $2.37 \pm 0.52\%$ and $2.60 \pm 0.42\%$ for *Zea mays* and *Vigna unguiculata* respectively; the percentages of seeds damaged were

reduced to $0.26 \pm 0.13\%$ and $0.05 \pm 0.05\%$ for *Zea mays* and *Vigna unguiculata* respectively. There were no significant differences between leaves powders applied and insecticide used for the percentages of weight loss and seeds damaged. Indeed, all leaves powders have significantly reduced the weight loss and seeds damaged during the experiment. For the weight loss, *V. amygdalina* and *O. gratissimum* leaves powders were more potent, with $4.49 \pm 0.75\%$ for *V. amygdalina* on *Zea mays* infested by *S. zeamais* and $3.29 \pm 0.92\%$ for *O. gratissimum* on *Vigna unguiculata* infested by *C. maculatus*. Concerning the seeds damaged *O. gratissimum* and *V. amygdalina* leaves powders were more potent on crops with $3.73 \pm 0.17\%$ for *O. gratissimum* on *Zea mays* and $0.85 \pm 0.13\%$ for *V. amygdalina* on *Vigna unguiculata*. With the control treatment, for both crops, the weight loss and the seeds damaged during the experiment, have reached a significant level as well for *Zea mays* as for *Vigna unguiculata*. In this case, the percentage of weight loss rose up $31.83 \pm 9.70\%$ and $34.45 \pm 9.96\%$ for *Zea mays* and *Vigna unguiculata* respectively; and the percentage of seeds damaged rose up $57.03 \pm 5.07\%$ and $54.27 \pm 4.24\%$ for *Zea mays* and *Vigna unguiculata* respectively.



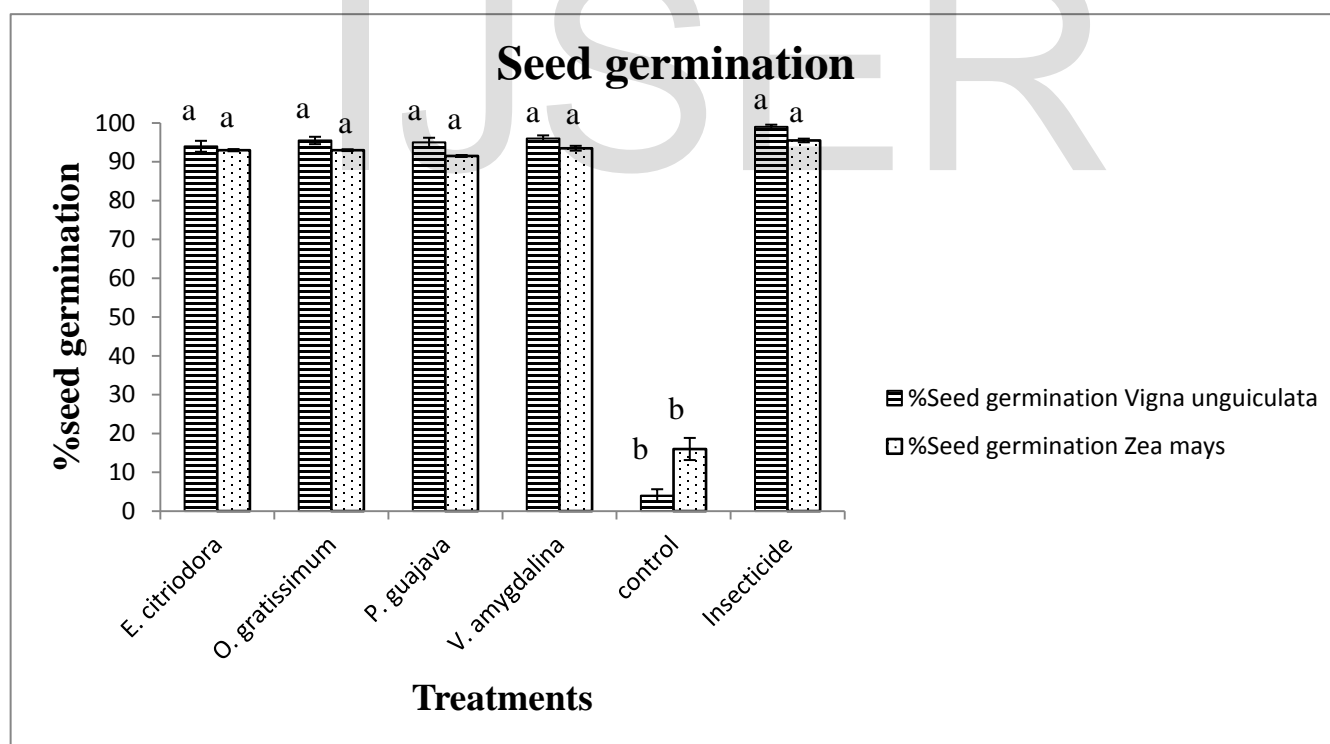
Influence of various leaves powders on emergence of insects' adults

The bar segments with the same alphabetic letter are not significantly different ($P > 0.05$) using the Student Newman-Keuls (SNK) test.

Figure 1: Number of adults emerged at F1 progeny.

The Figure 1 showed the effects of leaves powders used on F1 progeny of insects. The results showed that the number of adults emerged in treated jars were significantly lower than the number of insects recorded in control jars, ($p < 0.001$). Indeed, all the treatments used had reduced the adults' emergence. The number of adults emerged in the insecticide treatment was 0.25 ± 0.25 insects and 1.75 ± 0.85 insects for *C. maculatus* and *S. zeamais* respectively. For the leaves powders application, the means number of F1 progeny were not significantly different from the means number obtained in insecticide application. However, the lowest number of F1 progeny was obtained with *V. amygdalina* and *E. citriodora* leaves powders with 2.00 ± 0.91 insects for *V. amygdalina* on *V. unguiculata* infested by *C. maculatus* and 21.25 ± 4.15 insects for *E. citriodora* on *Z. mays* infested by *S. zeamais*. Concerning the control (untreated), the number of F1 progeny was the greatest number for both case, with 86.00 ± 13.88 insects and 164.50 ± 4.40 insects respectively for *C. maculatus* and *S. zeamais*.

Influence of various leaves powders on germination of crops (*Z. mays*, *V. unguiculata*) seeds



The bar segments with the same alphabetic letter are not significantly different ($P > 0.05$) using the Student Newman-Keuls (SNK) test.

Figure 2: percentage of crops seeds germinated

The percentages of seeds germinated at the end of the experiment are presented in Figure 2. The results obtained showed that at the end of the seeds germinated period, high

germination was observed with seeds having received insecticide and leaves powders application. Thus, the percentage of germination of seeds treated (insecticide, leaves powders) was significantly higher ($p < 0.001$) than germination of seeds untreated (control), as well for *V. unguiculata* seeds as for *Z. mays* seeds. In the case of insecticide application, the percentage of seeds germinated for both crops seeds was higher than others treatments (leaves powders). Indeed, there were no significant differences between leaves powders used and insecticide applied. All of the leaves powders used allowed having a high percentage of seeds germinated. For these treatments the lowest percentages of seeds germination were: $91.50 \pm 0.50\%$ and $94.0 \pm 1.41\%$ respectively for *P. guajava* on *Z. mays* infested by *S. zeamais* and for *E. citriodora* on *V. unguiculata* infested by *C. maculatus*. For the control (untreated), the percentage of seeds germinated was reduced to $16.00 \pm 5.71\%$ and $4.00 \pm 1.63\%$ for *Z. mays* infested by *S. zeamais* and *V. unguiculata* infested by *C. maculatus* respectively.

Discussion

The uses of chemical insecticide in the fight against insects led to several problems including environment pollution, human health, and insects' resistance. In rural area, these problems brought to food insecurity. Cowpea and maize are usually used as staple food in rural area, but are the most damaged cultures in storage. To protect the crops in postharvest condition without drawbacks, farmers must use botanicals products as insects' antifeedants or repellents, which are available, cheaper and which pose no threat to the environment or to human health. In the context of agricultural pest management, botanical insecticides are best suited for use in the production and postharvest protection of food in developing countries (Isman, 2006). Thus, the protective potency of various plants must be used in order to limit the damage after use of chemicals insecticides. Therefore, the searches of plants having protective characteristics comparably with chemicals insecticides become interesting.

The results obtained in this study showed that leaves powders of *V. amygdalina*, *O. gratissimum*, *P. guajava*, *E. citriodora* tested on insects' mortality were toxics. The activities of insects used were suppressed. All leaves treatments used had significant mortality on insects, except the control which have achieved the lowest and no-significant number of insects' mortality. The leaves powders used caused $100.00 \pm 0.00\%$ of mortality within 144h when the control achieved a number of mortality lower than 30.00% . These leaves powders have significant reduced the longevity of insects adult, *Callosobruchus maculatus* on cowpea seeds and *S. zeamais* on maize grains respectively. Indeed, most insects breathe through the

trachea which usually leads to the openings of the spiracles. These spiracles might have been blocked by the leaves powders and thereby leading to the insects suffocation, and then the death. With mortality test, the efficiency order of various leaves powders was: *V. amygdalina* > *O. gratissimum* > *P. guajava* > *E. citriodora* in the case of *S. zeamais* on *Zea mays*; and *V. amygdalina* > *O. gratissimum* > *E. citriodora* > *P. guajava* in the case of *C. maculatus* on *Vigna unguiculata*. These results showed the entomocidals capacities of the leaves powders used. (Brisibe *et al.*, 2011; Nguemtchouin *et al.*, 2013) have shown that insecticidal properties of *Ocimum gratissimum* had toxics effects on *S. zeamais* and *C. maculatus*. (Akunne *et al.*, 2013) showed that the leaves powders of *V. amygdalina* applied separately caused *C. maculatus* adults' mortality on *V. unguiculata*. (Kaloma *et al.*, 2008) have also shown the insecticidal activity of *E. citriodora* on *S. zeamais* in the Conservation of Maize (*Zea mays*).

The weight loss and seeds damaged obtained at the end of this experiment showed that all products (leaves powders and PROTECT DP®) used as crops protectants have allowed to obtain the lowest percentage of seeds damaged and weight loss as well for *Z. mays* grains as for *V. unguiculata* seeds. The control has achieved the highest percentage of seeds damaged and weight loss for both crops. Moreover, the reduction of percentage of weight loss and seeds damaged observed with leaves powders application would be due to the high mortality observed with leaves powders and thereby due to the insecticidal activities of various plants used. The leaves powders used were efficient on crops in terms of reducing of the percentage of seeds damaged and weight loss. Thus, the efficient order was: *V. amygdalina* > *P. guajava* > *E. citriodora* > *O. gratissimum* in the case of weight loss for *Zea mays*; and *V. amygdalina* > *O. gratissimum* > *P. guajava* > *E. citriodora* in the case of weight loss for *Vigna unguiculata*. *O. gratissimum* > *E. citriodora* > *V. amygdalina* > *P. guajava* in the case of seeds damaged for *Zea mays*; and *V. amygdalina* > *O. gratissimum* > *P. guajava* > *E. citriodora* in the case of seeds damaged for *Vigna unguiculata*. These results corroborate those obtained by (Kemabonta and Falodu, 2013) who showed that the use of *Moringa oleifera* leaves powders prevented the weight loss and seeds damaged.

The number of adults emerged at F1 progeny, showed the efficacy of various products used. The number of F1 progeny in the control jars was the highest number of adults emerged in this experiment. The products (leaves powders and PROTECT DP®) used, had significantly reduced F1 progeny. The reduction of F1 progeny within the leaves powders would be due to their insecticidal activities which had caused, significant mortality at the beginning of the experiment, inability of the eggs-lay to emerge, thereby reducing metabolic

activities of insects in this experiment. This F1 progeny reduction might also be because of the poor laying capacity of insects (*S. zeamais*, *C. maculatus*) due to physiological changes induced by leaves powders used on crops. The order of the effectiveness of the leaves powders on insects' emergence was: *V. amygdalina* > *O. gratissimum* > *P. guajava* > *E. citriodora* for F1 progeny of *C. maculatus* on *V. unguiculata*; and *E. citriodora* > *O. gratissimum* > *P. guajava* > *V. amygdalina* for F1 progeny of *S. zeamais* on *Z. mays*. These results are in conformity with (Ileke *et al.*, 2014) who observed that the seeds powders of *S. aromaticum* and the nuts powders of *A. occidentale* prevented adult emergence of *S. zeamais*. These results were also shown by (Mahdi and Rahman, 2008), who have reported the insecticidal effect of some spices powders on *Callosobruchus maculatus* (Fabricius) in black gram seeds.

The germination test at the end of the experiment showed that the percentage of germination was higher with treated seeds than untreated (control). Indeed, the leaves powders used in this experiment have allowed a significant germination of seeds (*V. unguiculata*, *Z. mays*). Moreover, these results might be due to the reduction of insects' (*S. zeamais*, *C. maculatus*) activities on crops seeds induced by the leaves powders applied. For this test, all of the leaves powders used had significant effects; nevertheless the efficacy order of the leaves powders on seeds germination was: *V. amygdalina* > *O. gratissimum* > *P. guajava* > *E. citriodora* for *V. unguiculata* seeds germinated and *V. amygdalina* > *O. gratissimum* > *E. citriodora* > *P. guajava* for *Z. mays* seeds germinated. These results corroborate those obtained by (Kaloma *et al.*, 2008) who stated that the use of powders of *Eucalyptus citriodora*, *Cupressus lucitanica* and *Tagetas minitiflora* on *Zea mays* and on *Phaseolus vulgaris* allowed having a high percentage of germination.

Conclusion

In this work, it has been experimented some leaves powders in the fight against two storage products insects (*S. zeamais*, *C. maculatus*). The results indicated and highlighted the entomocidal potency of leaves powders of *V. amygdalina*, *O. gratissimum*, *P. guajava* and *E. citriodora*. At the heart of this work, it appears that leaves powders used increased insects mortality and reduced weight loss, seeds damaged and F1 progeny. It also appears that plants powders used had no adverse effects on seeds germination. The leaves powders used had not only some entomocidals effects on insects, but also had restricted the insects activities on crops seeds treated. These results confirm the entomocidals activities of *V. amygdalina*, *O.*

gratissimum, *P. guajava* and *E. citriodora* on *S. zeamais* and on *C. maculatus* in post-harvest systems. The use of leaves powders is cheaper; they are easily available and safe. These plants used might be served as better sources of alternative to synthetic insecticides in post-harvest condition.

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