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Study of the Efficiency of the Aqueous Extract of *Azadirachta indica*'s Seeds and Deltamethrin on *Jatropha curcas* L. Insect Pests: Case of *Calidea panaethiopica* (Hemoptera: Scutelliridae) and *Aphtona whitfieldi* (Coleoptera: Chrysomelidae)

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Abstract

The efficiency of an aqueous extract of *Azadirachta indica*'s seeds and deltamethrin 12.5 EC was tested for the control of *Calidea panaethiopica* and *Aphtona whitfieldi* populations, two major insect pests of *Jatropha curcas* L. in Burkina Faso. This study was conducted in 2013 during the dry season and in 2014 during the raining season. In the laboratory, tests of toxicity by contact on paper blotter and by ingestion on organs of the plant and their repulsive effect on paper blotter were performed *in vitro* on the insect pests adults caught on *J. curcas* plantations as compared with controls. The aqueous excerpts of neem seeds were prepared at different lengths of steeping (12 h, 24 h and 48 h) and the deltamethrin 12.5 EC was diluted at different doses (4 ml, 8 ml and 16 ml/L). The results of this experiment showed the evidence of the efficiency of the doses 8 ml/L and 16 ml/L of deltamethrin 12.5 EC, and those of 24 h and 48 h for the excerpts of neem seeds. These efficient doses were evaluated in the field in 2013 and 2014. The highest decreases of *C. panaethiopica* (0.327) and of *A. whitfieldi* (0.501) populations were recorded with the 16 ml/L dose of deltamethrin in 2014 raining season. During the 2013 dry season, more insect pests were recorded (0.389 for *C. panaethiopica*

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and 0.679 for *A. whitfieldi*) with that dose. But these results were not significantly different from those of 8 ml/L. Regarding the *A. indica* extracts, the best decrease of populations in the 1st year (0.36 for *C. panaethiopica* and 1.278 for *A. withfieldi*) was recorded with the 48 h maceration. But in 2014 because of the effect of rainfalls that dose was less effective than that of 24 h maceration with 0.399 for *C. panaethiopica* and 1.208 for *A. whitfieldi*. The efficiency interval of the tested insecticides was two to three weeks in low or no rainfall conditions and one to two weeks in rainy season conditions.

Keywords

***Calidea panaethiopica*, *Aphtona withfieldi*, *Jatropha curcas*, Insectides**

1. Introduction

Since the oil crisis of the early 2000s, *Jatropha curcas* L. was identified by Effendi [1] as one of the alternatives to fossil fuels. It is a plant which is traditionally used as live-fence around fields, gardens, homesteads, etc. because of its toxic property which naturally keeps animals off. It is also used in medicine and its oil serves in the local manufacturing of soap [2].

In Burkina Faso, several reasons explain the increased production of *J. curcas*. According to [3], Burkina Faso imports over 400,000 metric tons of fuel every year, and this quantity keeps increasing. In fact, at present, 90% of the country's energy requirements are met with fire wood and charcoal, essentially deriving from national landmarks which are more and more shrinking [4].

Authors [5] rightly observed that in contradiction of the general belief that *J. curcas* was resistant to pests because of its toxicity, a large number of insects and other pests have been identified that can severely reduce growth and yield [6]-[8]. *Calidea panaethiopica* and *Aphtona withfieldi* are part of these insect pests [5] [9] [10]. *Calidea* spp. are polyphagous insects of the *Scutelleridae* family (Heteroptera). *Calidea panaethipica* is a Heteroptera of the *Scutellaridae* family. It is a piercing-sucking insect that damages fruit and inflorescences resulting in yield loss and the depreciation of seeds quality. According to [10] they are insect pests of cotton in Tanzania and of sorghum and sunflower in South Africa [11]. Author [12] showed that the presence of the insect pest in a cotton field is often very short, and the pest attacks only the bolls that are not yet open. Author [11] reported on *Calidea* spp. in *J. curcas* plantations in Guinea-Bissau where they were responsible for severe damage to seed production and the quality of the oil. The larvae and the adults attack the fruit and flowers of *J. curcas* by piercing the young seeds and causing the depreciation of their commercial value.

On the opposite, *A. withfieldi* is a Coleopteran of the *Alticinae* sub-family. It is a chewing insect that attacks the leaves of *J. curcas*' plants entailing their fall. Authors [5] showed that several studies had identified flea beetles of the genus Aphthona (Coleoptera: Chrysomelidae, Alticinae) as major pests of *J. curcas* in various regions in Africa [6] [9] [13]-[15]. These insect pests are known to be particularly damaging to young plants, which can die from continuous defoliation. Even when the plant is not killed, growth and fructification are severely hampered [6] [9] [13] [15]. It is only just recently that [16] clarified the taxonomy of the genus Aphtona and described the species in West Africa as *Aphtona whitfieldi* Bryant [5]. The same species is also reported by [17] as damaging *J. curcas* in Kenya, but [16] identified other specimens reared from *J. curcas* in Kenya as *A. cookei* (Gerstaecker) [5]. Authors [5] also reported on *Aphthona dilutipes* Jacobi, a Southern African species and an undescribed species that were reared from *J. curcas* according to [13]. Finally, the Aphthona genus is absent or is "of minor importance on *J. curcas* in dryer regions such as Niger [18], Sudan [19], and Senegal [20]".

Few authors have investigated the control of insect pests of *J. curcas.* Because of low inputs used in *J. curcas* plantations in Africa, priority should be given to cultural control. In Burkina Faso, the shrub is in general intercropped with food and cash crops [21]. In this case, it is recommended to avoid any association between *J. curcas* and other Euphorbiacea species that may share the same insect pests' complex with the shrub [22]. Regular pruning of the plant can avoid the spread of insect pests and diseases associated with *J. curcas* [23]. Jatropha Mali Initiative has started a breeding program that aims at developing more productive and tolerant/resistant varieties of *J. curcas* to the key insect pests and diseases in Mali [24]. Some authors have investigated the chemical control of *J. curcas*' insect pests and diseases. Authors [25] recommend the application of Carbosulfan and Imidacloprid at the period of fruiting to control sucking insects. But given the many drawbacks related to cost and use of pesticides in recent years, efforts to *J. curcas* protection were more oriented towards the use of biological agents and plant extracts, alone or in combination [22]. To this end, several plants including neem (*Azadirachta indica*) and their constituents are used to control pests of the plant. These biopesticides have a real advantage over their chemical counterparts because of their low persistence, their low toxicity to humans and their mode of action on pests. Finally, some authors have investigated the potential of biological control of insect pests of *J. curcas* in Africa or Asia. These include [7] [18] [25] and [26].

In this paper, we evaluate the efficacy of a botanical insecticide and a pyrethrinoid vis-à-vis two key insect pests of *J. curcas* in Burkina Faso.

2. Material and Methods

2.1. Material

2.1.1. Plant Material

J. curcas represents the plant material used in this study. The plantations in which the insect pests were collected for the laboratory experiments were either pure plantations or live fences or plantations associated with some other crops such as groundnut, sorghum, cowpea, soybean, etc. A plantation of *J. curcas* associated with cowpea was used for the field experimentation in Mouna, a village located at 4 km North to Léo, the capital city of the Sissili province, South Burkina Faso. This plantation was implemented in 2010 with double *J. curcas* lines separated with two m between lines and eight m between double rows.

2.1.2. Insects' Material

The studied animal species were *C. panaethiopica* and *A. withfieldi*. These are two of the major insect pests associated with *J. curcas*.

2.1.3. Insecticides

Deltamethrin: Deltamethrin is a photo stable, second generation pyrethrinoid. It consists of a white powder up to 190˚C and lightly volatile. It is soluble in organic solvents and its photo stability is of three to four weeks. The product used in this study is 12.5 EC formulation deltamethrin; it is an emulsionable concentrate with 12.5 g of deltamethrin active ingredient per liter.

Azadirachtin: The decomposition and extraction of the various chemical species contained in the neem show the presence of numerous active ingredients, which complementary's actions are at the origin of the insecticide features of neem. According to [27], the aqueous extracts of neem seeds contain more than 168 compounds consisting in a group of seven close substances including Azardirachtin. Namely, they are triterpenoids. Azadirachtin A is very largely considered as the major compound of neem with insecticide properties, even if it was demonstrated that, by itself, it was not sufficient to justify the remarkable properties of neem [28].

2.2. Methods

2.2.1. Field Experimental Site Selection

A prospection was conducted in order to decide on the best *J. curcas* plantation that could host the experiment. The best plantation is the one that is infested by the two insect species studied in this study. It must be easily accessible to enable the rapid implementation of activities. Besides, that plantation should be able to accommodate four replicates of five treatments.

2.2.2. Method of Insecticides Preparation

The solution composed of Azadirachtin.

The solutions composed of neem seeds were obtained in the following manner and inspired from [29]:

Solution 1: 2.90 kg of crushed neem seeds + 10 liters of water + maceration for 12 h (that is 0.29 kg/l);

Solution 2: 2.90 kg of crushed neem seeds + 10 liters of water + maceration for 24 h (that is 0.29 kg/l);

Solution 3: 2.90 kg of crushed neem seeds + 10 liters of water + maceration for 48 h (that is 0.29 kg/l).

2.2.3. Solution Composed of Deltamethrin 12.5 EC

The following doses were tested:

Solution 1: 0.06 liter of Deltamethrin 12.5 EC + 15 liters of water that is 4 ml/L of water;
Solution 2: 0.12 liter of Deltamethrin 12.5 EC + 15 liters of water that is 8 ml/L of water;
Solution 3: 0.24 liter of Deltamethrin 12.5 EC + 15 liters of water that is 16 ml/L of water.

2.2.4. Laboratory Experiment

All laboratory tests were conducted at a mean temperature of 30.82˚C and a mean relative humidity of 65.69%.

2.2.5. Toxicity by Contact of Insecticides on Blotting Paper

The various types of each insecticide were evenly shed on blotting paper that covered the bottom of a plastic can. Thus, a set of 10 adult insect pests of each species was introduced in each can that had the treated blotting paper, with a non-treated control. Then, the cans were immediately closed. Four replications were implemented for each dose; the dead insects were counted (maintained in the cans); every 24 h for 4 days.

Mortalities in the treated cans (Mo) were expressed according to Abbott's formula in adjusted mortality (Mc) to take into account the natural deaths observed in the control can (Mt). That formula is written as follow:

$Mc = (Mo - Mt)/(100 - Mt) * 100$ [30]

Mc: Adjusted mortality; Mt: Mortality in the control can; Mo: Mortality in the treated cans.

2.2.6. Toxicity by Injection of Insecticides on the Plant's Organs

Like previously, three doses of each insecticide were used. In each can, three fruit of *J. curcas* were placed in the case of *C. panaethiopica*, and three leaves in the case of *A. withfieldi* after having coated the various doses with solutions. The control can was not treated. Four replications were implemented for each dose, and then each can was infested by a set of 10 adult insect pests of each species. The count of dead insects was conducted every 24 h for four consecutive days.

Mortalities in the treated cans (Mo) were expressed according to [30] formula in adjusted mortality (Mc) in order to include the natural deaths observed in the control can (Mt). That formula is written as follow:

$Mc = (Mo - Mt)/(100 - Mt) * 100$ [29].

2.2.7. Repellent Effect of Insecticide on Blotting Paper

The repellent effect of insecticides with respect to the adult insect pests was assessed using the preferential zone method on blotting paper described by [31]. The blotting paper intended to cover the bottom of the cans was cut into two equal parts. Then, each of the prepared solutions was evenly poured over one half of the blotting paper placed in the bottom of the can and the other half that was not treated (coated with water so that it does not absorb the solutions) was placed in the can to cover the remaining bottom. A set of ten adult insect pests of each species was introduced in the cans. Four replications for each dose were implemented.

After two hours, the number of insect pests that were present on the treated part of the blotting paper and the number of those that were on the non-treated part were recorded.

The percentage of repulsion (PR) was expressed using the formula:

$PR = (Nc - Nt)/(Nc + Nt) * 100$; with Nc: number for the non-treated part and Nt: number for the insecticide part.

The mean percentage of repulsion for essential oil was calculated and classified according to the classification of [31] in one of the repellent classes ranging from 0 to V: class 0 (PR < 0.1%), class I (PR = 0.1% - 20%), class II (PR = 20.1% - 40%), class III (PR = 40.1% - 60%), class IV (PR = 60.1% - 80%) and class V (PR = 80.1% - 100%).

2.2.8. Field Experiment

A randomized complete bloc design including five treatments and four replications was used. The insect pests, *C. panaethiopica and A. withfieldi* were counted on five individual plants randomly selected from each treatment. This allowed an estimation of the number of insect pests initially present in each treatment. The distribution of doses was randomly done on all five rows that were to receive pesticide applications. Pesticides were sprayed on the leaves of *J. curcas* trees that were randomly selected for this purpose. Pesticide applications were repeated every three weeks and observations were conducted weekly according to the following objectives:

1) the frequency of live *C. panaethiopica* and *A. withfieldi* in the treatments;
2) the frequency of dead *C. panaethiopica* and *A. withfieldi* in the treatments.

The 2013 experiment was implemented in October and therefore received only some few rains. Meanwhile, the mean monthly rainfall was 86.3 mm. Therefore, the effect of rain water on the treatments was very low, rather negligible. The 2014 experiment was implemented early August, with a mean monthly rainfall of 110.8 mm.

2.2.9. Statistical Analysis

An analysis of variance and a comparison of means "Protected Least Significant Difference (PLSD)" at 5% significance were conducted on the data collected in the laboratory and in the field using Stat View version 5.0.0.0 software in order to compare the effects of the treatments on the insect pests. Data collected in the field were submitted to a Log_{10} (2 + x: x being the number of observed insects) transformation before they were analyzed. Figures were prepared using Excel, Microsoft Office 2010.

3. Results

3.1. Toxicity Test of Insecticides by Contact on Blotting Paper

3.1.1. Effect of Aqueous Extract of Neem Seeds and Deltamethrin 12.5 EC on *C. panaethiopica* by Contact

Figure 1 shows the evolution of percentages of cumulative and adjusted deaths compared to the control of *C. panaethiopica*'s adults in relation with time and doses of insecticides. A variation of the level of mortality can be observed in relation with the various doses of insecticides and time frame. The highest dose of deltamethrin 12.5 EC (16 ml/L) provoked more than 90% of mortality on the second day of observation whereas the other doses, 4 ml/L and 8 ml/L respectively yielded 52.77% and 61.11% of mortality. On the opposite, the aqueous extract of neem seeds macerated for 24 h provoked the highest mortality (75.86%) on the fourth day of exposure contrary to extracts macerated for 12 h and 48 h which respectively yielded only 5.72% and 68.96% mortality.

The analysis of variance (ANOVA) indicated a highly significant difference between treatments at 5% level. It showed a distinction between 16 ml/L of deltamethrin 12.5 EC and 12 h as well as 48 h of maceration of the neem extract. This ANOVA also indicated a peculiarity between 4 ml/L and 8 ml/L of deltamethrin 12.5 EC with the aqueous extract of neem seeds macerated for 12 h; but there was no significant difference between the doses (4 ml/L; 8 ml/L and 16 ml/L) of deltamethrin 12.5 EC and the neem seeds extract macerated for 24 h. It also indicated a significant difference between the various doses and the control.

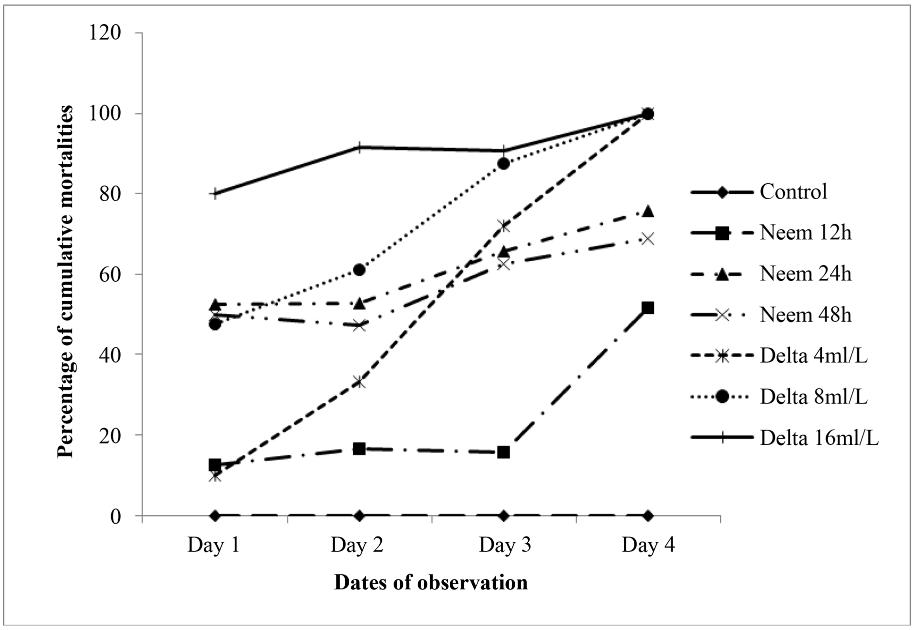

Figure 1. Evolution of percentages of cumulative mortalities of *C. panaethiopica*'s adults in accordance with time and with doses of deltamethrin 12.5 EC and aqueous extract of neem seeds.

3.1.2. Effect of Aqueous Extract of Neem Seeds and Deltamethrin 12.5 EC on *A. whitfieldi* by Contact

Figure 2 shows the evolution of the percentages of cumulative and adjusted mortalities compared with the control of *A. withfieldi*'s adults in relation with time frame and doses of the insecticides that were used. A similarity of mortality rates is observed with the various doses of insecticides and with time. All the doses of deltamethrin 12.5 EC (4 ml/L, 8 ml/L and 16 ml/L) and of the aqueous extract of neem seeds (12 h, 24 h and 48 h of maceration) provoked a total mortality (100%) on the first day of exposure on blotting paper. Henceforth, the insecticide activity of these six doses was similar when these products were in contact with *A. whitfieldi*.

The ANOVA indicated no significant difference between the solutions and between the various doses at 5% level. On the opposite, it revealed a highly significant difference between the different doses of the two insecticides and the control.

3.2. Toxicity Test of Insecticides by Ingestion of the Plant's Organs

3.2.1. Effect of Aqueous Extract of Neem Seeds and Deltamethrin 12.5 EC on *C. panaethiopica* by Ingestion of *J. curcas*' Fruit

Figure 3 shows the evolution of percentages of cumulative and adjusted mortalities in comparison with the control adults of *C. panaethiopica* in relation with time and doses of insecticide used. A variation was observed on the mortality rate in relation with the various doses of insecticide and time. But right from the 2nd day, different doses of deltamethrin 12.5 EC reached nearly 100% of mortality after ingestion. On the opposite, the aqueous extracts of neem seeds macerated for 12 h, 24 h et 48 h have reached their maximal mortality on the fourth day of ingestion with respectively 29.41%; 67.64% and 58.82%. Henceforth, the insecticide activity of these three doses of deltamethrin 12.5 EC was almost similar when these products were ingested by *C. panaethiopica*.

Regarding the aqueous extract of neem seeds, the ANOVA indicated a highly significant difference between the dose of 24 h maceration and the control, and not with the 12 h and 48 h. There was no significant difference between the various doses of deltamethrin that were used (4 ml/L, 8 ml/L and 16 ml/L). But regarding the interaction between the two insecticides, the ANOVA revealed a significant difference between all the doses of deltamethrin 12.5 EC and those of the aqueous extract of neem seeds.

3.2.2. Effect of Aqueous Extract of Neem Seeds and Deltamethrin 12.5 EC on *A. whitfieldi* by Ingestion of *J. curcas*' Leaves

Figure 4 shows the evolution of the percentages of cumulative and adjusted mortalities in comparison with the

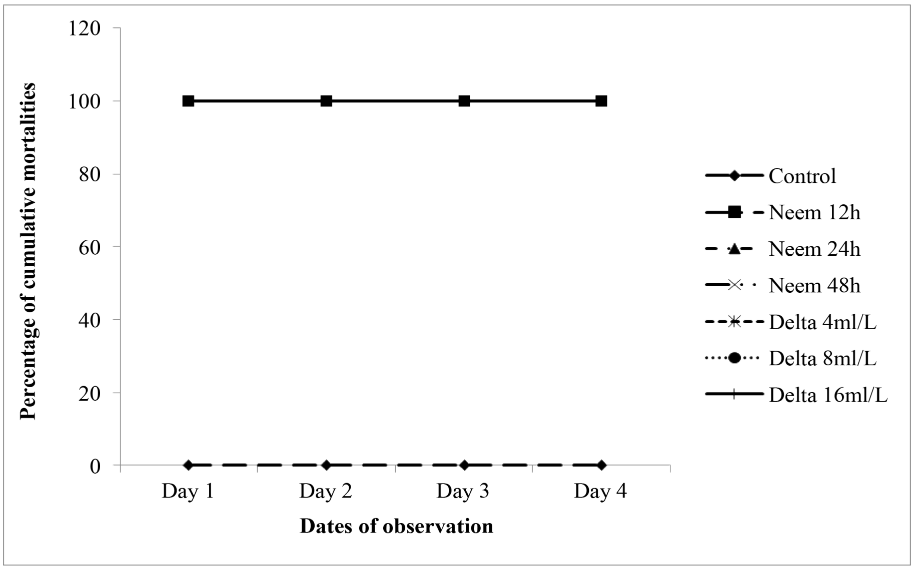

Figure 2. Evolution of percentages of cumulative mortalities of *A. withfieldi* in accordance with time and doses of deltamethrin 12.5 EC and the aqueous extract of neem seeds after contact on blotting paper.

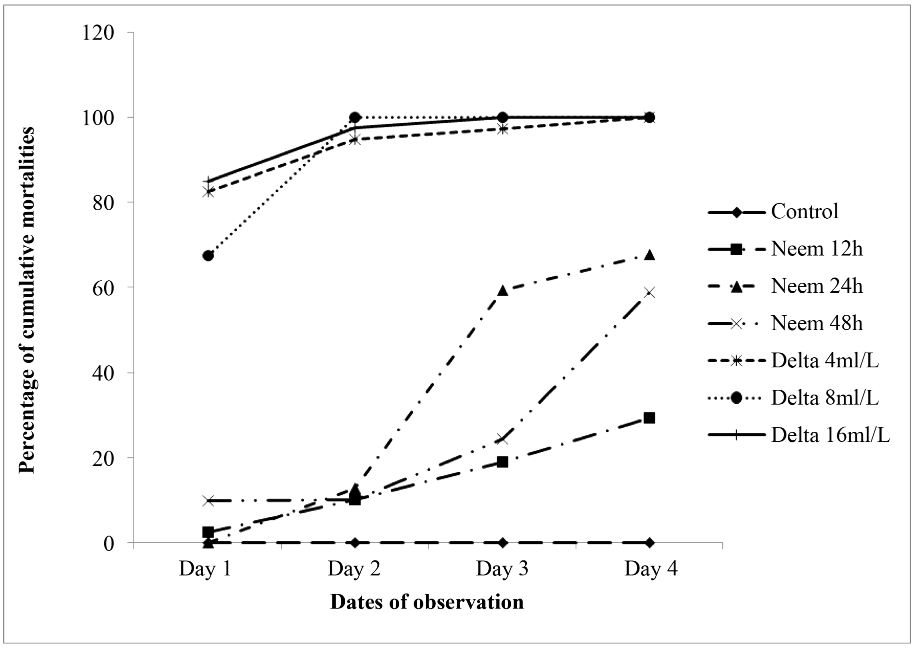

Figure 3. Evolution of percentages of cumulative mortalities of *C. panaethiopica*'s adults in relation with time and doses of deltamethrin 12.5 EC and aqueous extract of neem seeds after ingestion of *J. curcas*'s fruit.

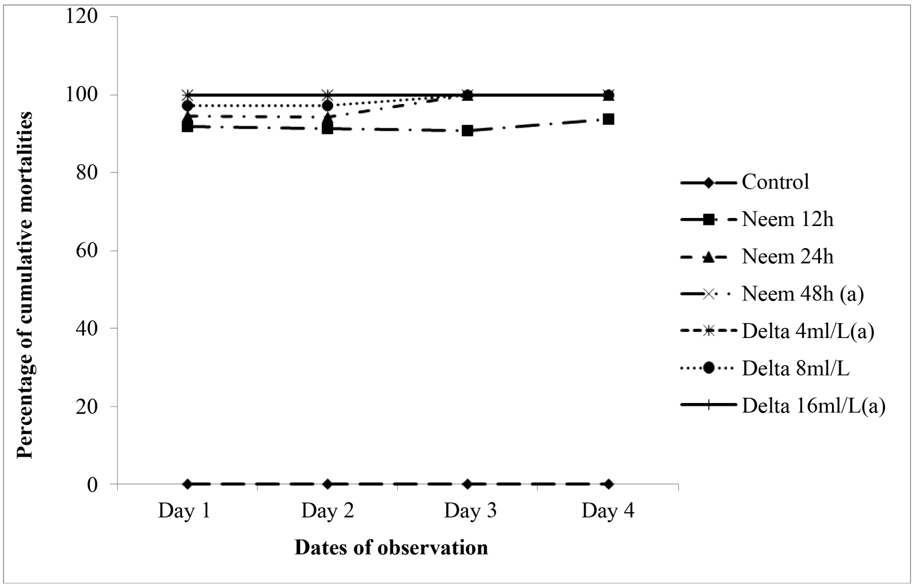

Figure 4. Evolution of percentages of cumulative mortalities of *A. whitfieldi*'s adults in relation with time and doses of deltamethrin 12.5 EC and with the aqueous extract of neem seeds after ingestion of *J. curcas*' leaves.

control of *A. whitfieldi*'s adults in relation with time and doses of the insecticides used. An almost similarity of mortality rates of the insect pest could be observed in relation with the various doses of the insecticides and time. The doses of deltamethrin 12.5 EC 16 ml/L and 4 ml/L and that of the aqueous extract of neem seeds macerated for 48 h provoked a total mortality (100%) on the first day of ingestion but it was only on the 3rd day that the 8 ml/L deltamethrin 12.5 EC and the 24 h maceration of neem seeds' extract reached 100% mortality; the 12 h maceration reached only 93.75% on the 4th day. Subsequently, the insecticide activity of these three doses was similar when these products were ingested by *A. whitfieldi*.

The ANOVA revealed a significant difference between the doses of the neem aqueous extract after their ingestion by *A. whitfieldi*. No significant difference between the doses of deltamethrin 12.5 EC was shown either.

3.3. Test of Repellent Effect on the Insecticides on the Blotting Paper

3.3.1. Repellent Effect of the Aqueous Extract of Neem and Deltamethrin 12.5 EC on *C. panaethiopica*

The percentages of repulsion of the various doses of the two insecticides (aqueous extract of neem seeds and deltamethrin 12.5 EC) are summarized in **Table 1**. After two hours exposure, the various doses (12 h, 24 h and 48 h maceration) of the aqueous extract of neem seeds resulted in 25%, 55% and 48.71% respectively of repulsion regarding *C. panaethiopica*'s adults. On the opposite, the doses of deltamethrin 12.5 EC (4 ml/L, 8 ml/L and 16 ml/L) provoked 85%, 90% and 100% of repulsion respectively. This clearly shows that the percentage of repulsion increases with the dose of insecticide.

The classification of the treatments was based on the percentage of repulsion of the insect pests as follow:

% of repulsion	Class type
<0.1	0
0.1 - 20	I
20.1 - 40	II
40.1 - 60	III
60.1 - 80	IV
80.1 -100	V

3.3.2. Repellent Effect of the Aqueous Extract of Neem and Deltamethrin 12.5 EC on *A. whitfieldi*

The percentages of repulsion of the two insecticides (the aqueous extract of neem seeds and deltamethrin 12.5 EC) are presented in **Table 2**. After two hours exposure, the various doses (12 h, 24 h and 48 h maceration) of the aqueous extract of neem seeds provoked 43.75%, 80% and 77.27% respectively of repulsion of *A. whitfieldi*'s adults. But the doses of deltamethrin 12.5 EC (4 ml/L, 8 ml/L and 16 ml/L) provoked only 35.3%, 19.04% and

Table 1. Percentage of repulsion of the aqueous extract of neem seeds and of deltamethrin 12.5 EC on blotting paper regarding *C. panaethiopica*'s adults.

Treatments	Percentage of repulsion	Class type
Neem 12 h	25	II
Neem 24 h	55	III
Neem 48 h	48.71	III
Deltamethrin 4 ml/L	85	V
Deltamethrin 8 ml/L	90	V
Deltamethrin 16 ml/L	100	V

Table 2. Percentages of repulsion of the aqueous extract of neem seeds and of deltamethrin 12.5 EC on blotting paper regarding *A. whitfieldi*'s adults.

Solutions	Percentage of repulsion	Class type
Neem 12 h	43.75	III
Neem 24 h	80	IV
Neem 48 h	77.27	IV
Deltamethrin 4 ml/L	35.3	II
Deltamethrin 8 ml/L	19.04	II
Deltamethrin 16 ml/L	14.28	I

14.28% respectively of repulsion. These results also indicate that the percentage of repulsion of the insect pest was correlated with the dose.

3.3.3. Effect of Aqueous Extract of *A. indica* Seeds and of Deltamethrin 12.5 EC on *C. panaethiopica*

The ANOVA revealed a significant difference at 5% level between the different insecticide doses for the number of dead *C. panaethiopica* regardless of the year (**Table 1**). Clearly, the doses of deltamethrin 12.5 EC, henceforth, 16 ml/L (0.386) and 8 ml/L (0.376) were not significantly different from one another and those of the aqueous extracts of *A. indica*'s seeds were not significantly different either with 0.336 for 48 h maceration and 0.336 for 24 h. *A contrario*, the doses of deltamethrin 12.5 EC resulted in a significant difference as compared to the aqueous extracts of *A. indica*'s seeds and the control. The aqueous extracts of *A. indica*'s seeds produced no significant difference as compared to the control which produced 0.301. These results are similar to the ones observed in the 2nd year with a slight inferiority whereby the different doses resulted 16 ml/L (0.38), 8 ml/L (0.353), 48 h (0.316), 24 h (0.313) and the control (0.301). Regarding *C. panaethiopica* that were alive, there was also a significant difference between the different treatments. Regarding the 1st year, the ANOVA revealed no significant difference between the two doses, 16 ml/L (0.327) and 8 ml/L (0.329) of deltamethrin 12.5 EC but they were significantly different from the control (0.526) and from the lowest concentration of *A. indica*'s seeds' extract (24 h = 0.462). They were not significantly different from the 48 h macerated extract (0.36). Nonetheless, in the 2nd year, there was no significant difference between the insecticides as well as the tested doses, only the 16 ml/L (0.389) dose of deltamethrin 12.5 EC was different from the control (0.474). The evolution of cumulated means of dead or alive *C. panaethiopica* is illustrated by **Figure 5** and **Figure 6**. The cumulated means of the insect

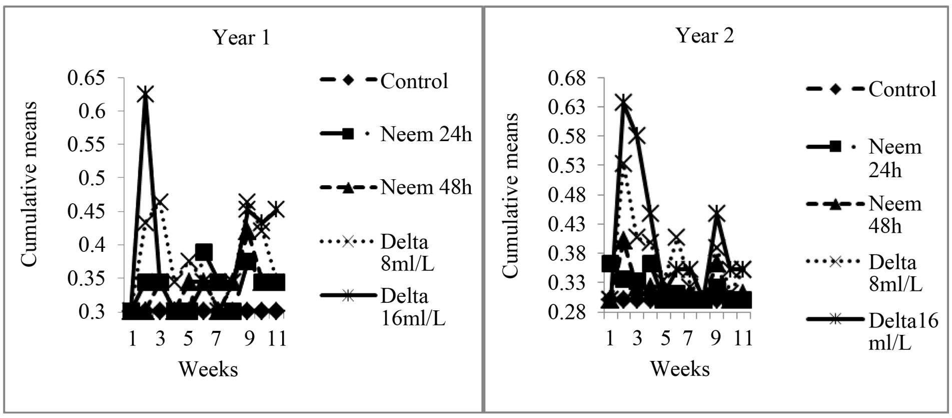

Figure 5. Evolution of the cumulative means of dead *C. panaethiopica* adults according to time and to doses of deltamethrin 12.5 EC and to the aqueous extracts of *A. indica*'s seeds after insecticide applications in the field.

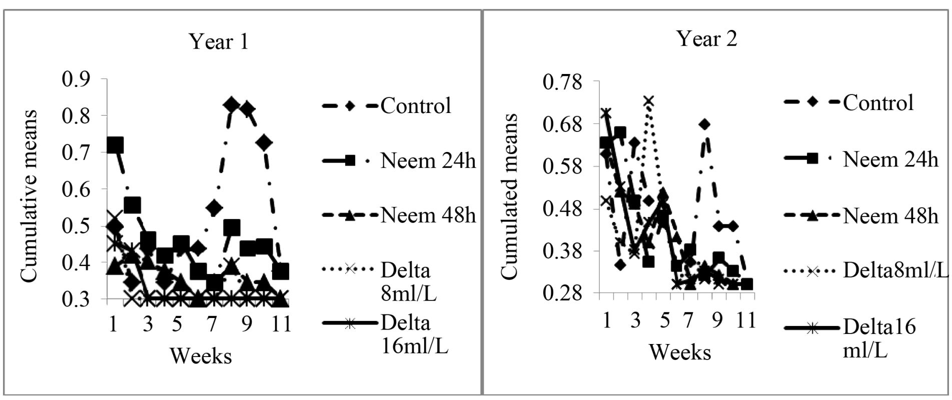

Figure 6. Evolution of the cumulative means of living *C. panaethiopica* adults according to time and to doses of deltamethrin 12.5 EC and to the aqueous extracts of *A. indica*'s seeds after insecticide applications in the field.

individuals varied according to the doses of insecticide and the dates of application in both 1st and 2nd year. Generally, after each application, the cumulative numbers of *C. panaethiopica* which were alive gradually decreased while that of the dead insects increased after each treatment, irrespective of the dose of insecticide that was used. But regarding the control, the number of living insects was generally increasing and the number of dead ones was almost zero.

3.3.4. Effect of Aqueous Extract of *A. indica* Seeds and of Deltamethrin 12.5 EC on *A. whitfieldi*

The ANOVA revealed a significant difference at 5% level between the various doses tested for the number of dead and living *A. whitfieldi* after application of the insecticides in each year. Nonetheless, in the 1st year, for mean numbers of dead *A. whitfieldi* the 2 doses 16 ml/L (0.767) et 8 ml/L (0.741) of deltamethrin 12.5 EC were not significantly different from each other, but they were with respect to the control (0.309) and to the aqueous extract of *A. indica*'s seeds for 24 h (0.537). The two extracts of *A. indica*'s seeds were not significantly different from each other but differed significantly from the control. When confronted with the mean numbers observed in the 2nd year, the efficiency of doses was alike but numerically higher than those of the 1st year. Henceforth, we had 0.953 for 16 ml/L; 0.914 for 8 ml/L of deltamethrin 12.5 EC; 0.676 for 48 h; 0.59 for 24 h maceration, and for the control 0.343. Regarding the living insect pests, the two doses of deltamethrin 12.5 EC, 16 ml/L (0.501) and 8 ml/L (0.562) were the most efficient. Then, they were followed in efficiency order by *A. indica*'s maceration extracts of 24 h (1.235) and 48 h (1.278), and the control (1.38). These results which were observed in the 1st year were similar to those recorded in the 2nd year but also with a numerical superiority despite the effect of rainfalls.

In general, for that insect, a considerable decrease in the cumulative means of the livings from one dose to another and according to the dates of insecticide application (**Figure 7**) was observed. Regarding the cumulative means of the dead pests, they increased considerably after each treatment (**Figure 8**). It was therefore noticed that the evolution of the different curves was not function of the years because each application had an effect on the insects, though at slightly different amplitude.

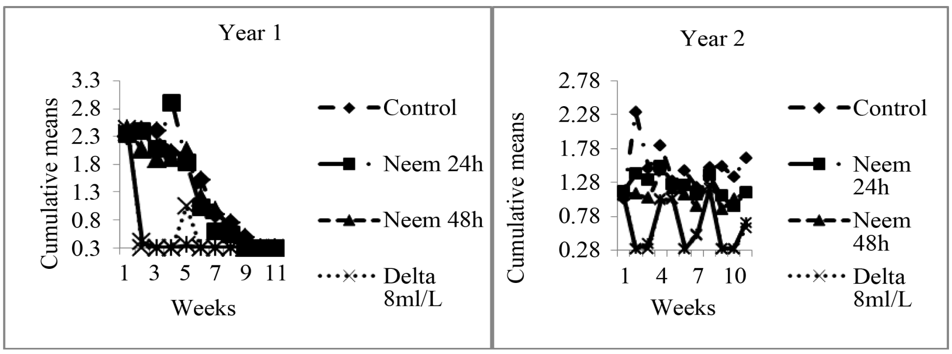

Figure 7. Evolution of the cumulative means of living *A. whitfieldi* adults according to time and to the doses of deltamethrin 12.5 EC, and to the aqueous extracts of *A. indica*'s seeds after insecticide applications in the field.

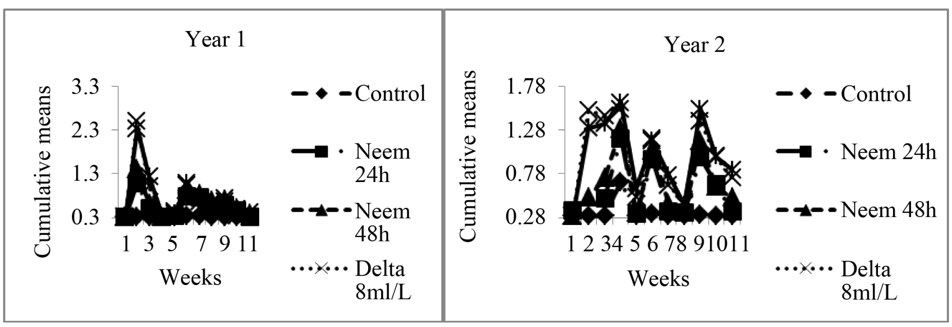

Figure 8. Evolution of the cumulative means of dead *A. whitfieldi* adults according to time and to the doses of deltamethrin 12.5 EC, and to the aqueous extracts of *A. indica*'s seeds after insecticide applications in the field.

4. Discussion

The 2013 experiments were conducted in October where only 86.3 mm rainfall was recorded. Therefore, this period can be considered as the start of the dry season. Thus, the effect of rainfall on pesticide applications was very low or negligible. The 2014 experiment was implemented from early August, and was therefore strongly influenced by heavy rains at short frequency. Average monthly rainfall was 110.8 mm. Thus, the two doses of the aqueous extracts of *A. indica*'s seeds and of deltamethrin 12.5 EC were actually tested in these conditions. These doses were 8 ml/L and 16 ml/L for deltamethrin 12.5 EC, and 24 h and 48 h of maceration for the aqueous extracts of *A. indica*'s seeds. By and large, it showed that the application of the doses of deltamethrin 12.5 EC and of the aqueous extracts of *A. indica*'s seeds resulted in a significant decrease in the number of *C. panaethiopica* and *A. whitfieldi* individuals. It also entailed an increase of the mortality ratio of each species comparatively to the control.

Data recorded weekly on the mortality and the presence of the insect pests was rather contrasted. Thus, the ANOVA revealed significant differences between the treatments with a high number of living *C. panaethipica* and of *A. whitfieldi* in the control. This low level of the targeted insect pests in the sprayed rows could be due on one hand to a relative decrease in the population of these insect pests during the application period and on the other hand, to the effect of the insecticides that were used. In the latter case, the low level was function of the doses and of the kind of insecticide. But for the 2nd year, it evolved in saw-tooth rate for the two variables that were observed as compared to the 1st year that was decreasing for the living populations and increasing for the non-living ones.

The low means of *C. panaethiopica* and of *A. whitfieldi* that were recorded with the 16 ml/L doses of deltamethrin 12.5 EC, and of the 48 h aqueous extract of *A. indica*'s seeds would explain the efficiency of these insecticides at the doses that were used. Notwithstanding rainfall conditions, the analysis of the results of mean number of insect pests also showed a high mortality inflicted by the two latter doses of deltamethrin 12.5 EC after each application. Generally, deltamethrin 12.5 EC was more efficient in controlling the targeted insects than the aqueous extracts of *A. indica*'s seeds and the control. But these doses were more efficient in the 1st year, a year when the effects of rainfalls on the applications were little and even nil as compared to the 2nd year of the experiment where the rainfalls affected the applications. That action of rainfalls is henceforth felt regarding the low mortality ratio for that year. This influence would be the washing of products by the rain-waters after the applications, thereby reducing their action. The action of deltamethrin 12.5 EC was also reported by [32] on cantharides which were Coleopteran like *A. whitfieldi* and on plant bugs (Hemipetera like *C. panaethiopica*). In the specific case of *A. whitfieldi*, the decrease in its population in the 1st year could be associated with the biological cycle of the insect because that was observed even in the non-sprayed control and in the plantations neighboring *J. curcas*' plantations. Author [33] reported the decrease in the *A. whitfieldi* population in the second half of October. These results were also observed in the second year of the experiment. This could explain the similarity of living populations of that insect pest which were observed in the control with those recorded with the aqueous extracts of *A. indica*'s seeds. Nonetheless, the mortalities inflicted by the doses of aqueous extracts of *A. indica*'s seeds with the two insect pests grant to these products, an insecticide feature regarding *A. whitfieldi* adults. When matching them, it was noticed that in the 2nd year, the mean of presence of living insects was very high and the mortality ratio was clearly inferior to that of the 1st year, this would further explain the influence of rainfalls on insecticide applications. This result is contradictory with the result reported by [34] who found that *Azadirachtin* couldn't control flea beetles such as *A. whitfieldi*, but would be efficient on plant bugs. Alongside with the results recorded with the aqueous extracts of *A. indica*'s seeds, [35] found that the aqueous extracts of *A. indica*'s seeds yielded interesting results on okra's flea beetles. Therefore, they control these insect pests. Also, it could be noticed that the decrease in population of each insect pest was not proportional to the increase of recorded deaths, and this could be explained, at first by the fact that dead insects were carried away by ants when they fell from the plant, and also by the fact that they were carried away by runoff waters before observations were made, mostly in the 2nd year; thirdly, this could be explained by the migration of insects from one tree to another one or from the sprayed plantation to the neighboring plantations. That migration of insects would be explained by the insect repellent character of the insecticides that were used as it is illustrated by the curves of "populations of living *C. panaethiopica* and *A. whitfieldi*''. The monitoring of insect pests during the applications also enabled us to approximately determine the persistence of the insecticides that were used. It lasted between two to three weeks in the experiment conditions in the 1st year and from one to two weeks in the 2nd year.

In the light of all these results, the 8 ml/L dose of deltamethrin 12.5 EC seems to be a good formula that is economically interesting. The 48 h maceration of *A. indica*'s extracts proves to be more efficient as compared to the 24 h maceration.

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