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Specific insecticidal action of three products of *Balanites aegypyiaca* on developmental stages of *Callosobruchus maculatus* (Coleoptera, Bruchidae)

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Abstract

The insecticidal effect of the powder of almonds, bark of the trunk and leaves from *Balanites aegyptiaca* against adults, eggs, larvae and young emerging of *Callosobruchus maculatus* was evaluated. 1g, 1.5g and 2g of individuals or combined powders of seeds (almonds) leaves and bark of the trunk of *Balanites aegyptiaca* were mixed with 100g of cowpea seed. The controls were made up with cowpea seed only. Four replications were performed on 20 pairs of weevils. The bark powder was the most effective on adults and young emerging of *Callosobruchus maculatus* with 100% effect after 3 and 16 days respectively. The almonds powder was the most effective on eggs after 9 and larvae after 16 days with 100 and 80% respectively of mortality. Regarding the combinations of the different plant powder, 100% of adult mortality rates and young emerging were obtained with 1.5g of combination, whereas the maximum rate of mortality of the eggs and larvae were obtained at a dose of 2g of mixture powder. Seeds powders and barks of *Balanites aegyptiaca* taken individually or combined offer the interesting perspectives to control against *Callosobruchus maculatus* in order to preserve cowpea during storage.

Keywords: Legumes, cowpea, powder, *Balanites aegyptiaca, Callosobruchus maculatus*

1. Introduction

Agriculture is an economic activity which purpose is the transformation and enhancement of the natural environment in order to obtain animal and plant products useful to man. It appears as one of the main elements on which the economic development of a country should be based [1, 2]. Today, agriculture faces constraints that lead to food insecurity in the world. These constraints include climate change, low agricultural yield and population growth [3]. From 2012 to 2015, chronic undernourishment affected nearly 805 million people over worldwide. An estimated 750 millions of these people live in developing countries [4]. Cameroon is one of these developing countries and more than 70% of its population is engaged in agriculture [5]. The crops grown in Cameroon and especially in the Far North Region are mostly cereals and leguminosis that are the staple food of populations [6]. Among these legumes, cowpea occupies a primordial place in the diet of the populations [6].

In Cameroon, since 2003, cowpea has taken over all other leguminosis with a contribution of 71.5% of planted area [3] hence there is need for storage. However, cowpea storage faces several challenges, including insect pests, favored by high temperatures in the Far North Region [7]. This constitute a major constraint to the realization of the yielding potential of cowpea, leading to a decrease in production and a total loss of the harvest product during storage if no action is undertaken [8].

The attack of cowpea seeds in particular by *Callosobruchus maculatus* (Coleoptera: Bruchidae) starts in the field and intensifies during storage. These cowpea seed insects perforate the seeds leaving several galleries, causing the quantitative losses (up to 30% of their mass) and qualitative losses [9].

To solve these problems, several control methods were used, including chemical, biological, mechanical, physical and varietal resistance [10, 11, 12, 13]. Some of these methods have been shown to be effective against *C. maculatus*. However, they have negative effects such as the intoxication of the various links in the food chain, the degradation of the environment, the lack of control of the ecological and morphological distribution of parasitoids, the high price of seedlings of resistant varieties, the reduction of the biodiversity, the reduction of beneficial and non-target organisms and insects respectively [14, 11, 15, 16, 17, 18]. In view of these disadvantages, it would be advisable to continue to look for other practices as the use of insecticidal plants for the storage of harvest product. Plant materials were reported to be effective, cheap and easily available for the control of insect pests of agricultural importance [19, 20]. This is why the exploration of other alternative methods becomes imperative. The use of different parts of *Balanites aegyptiaca* to control *C. maculatus* during storage has not been evaluated in the Far North Region of Cameroon. It is in this order of idea that we focused our principal objective to study the insecticidal activity of powders leaves, almonds and bark stem of *Balanites aegyptiaca* towards *C. maculatus* and specifically to assess the insecticidal effect of three powders of *B. aegyptiaca* taken individually or combined on adults, eggs, larvae and young emerging from *C. maculatus*.

2. Materials and methods

2.1 Rearing of *Callosobruchus maculatus*

The parental strains of *C. maculatus* used come from an experimental culture. The experiments were carried out with 48-hours old adults from mass rearing kept from the initial strains at IRAD Maroua laboratory. The average climate conditions of the laboratory were 33.55 ± 1.09°C and 20.1 ± 2.1% for relative humidity.

2.2 Obtention of the powders of *Balanites aegyptiaca*

The leaves, bark stem and almond of *B. aegyptiaca* were collected in Pitoare and Djarengol, two quarters of the city of Maroua (Far North Region, Cameroon). After collection, the fresh leaves were dried in the shadows for four days in the laboratory, to prevent the action of solar rays which releases the active molecules of the plant by enzymatic hydrolysis and induces the decrease of the insecticidal power of the different parts of the plants [21]. The leaves and the bark of the trunk were dried respectively for four and seven days. After drying, they were crushed in a mortar separately and sieved with a 0.85mm diameter sieve. For almonds, the fruits were soaked in water for four days and then washed to rid the pulps. The cores obtained were dried for two weeks and then crushed to remove the seeds. These seeds were dried for one week, crushed in a mortar and finally sieved. The different powders were stored in 500mL jars and well closed in laboratory.

2.3 Assessing toxicity of the different powders of *Balanites aegyptiaca* on *Callosobruchus maculatus*

2.3.1 Infestation

The seeds of cowpea (*V. unguculata*) used for all the trials belong to the variety Vya from Moutourwa district (Maroua, Far north region). Certainly, this variety is not only the most sensitive but it is also the most popular. According to our surveys, the population claims that they preferred that variety because it is sweet in the fresh state, easy to wash and prepare. Moreover, that variety has a very short development cycle. The variety is grown during the dry season and is abundant when all other varieties are in short supply at the market. The untreated seeds were cleaned and stored in a refrigerator at 4°C in order to prevent infestation. Before their use, the cowpea seeds used were allowed to acclimatize for twenty hours under ambient laboratory condition.

2.3.2 Evaluation of the insecticidal effect of the three powders individually or combined from *Balanites aegyptiaca* on adults of *Callosobruchus maculatus*

100g of healthy cowpeas were measured using a Lutron GM-300p brand electronic scale (300.00g x0.01g) and introduced into jars initially labeled with four replications. 1g, 1.5g and 2g of leaf powder, bark or almond of *B. aegyptiaca* were introduced and mixed manually with 100g of cowpea initially weighed. The combination of the three powders used consists to take 1/3 part of each product.

Ten couples of bruchids of 48 hours olds were introduced after in each jar after the application of treatment with or without plants products. These bruchids were sexed using the elytra pattern [22]. Three days (72 hours) after infestation, the contents of the jars were sieved in order to count the number of dead. The criterion of mortality corresponds to an insect that can no longer walk or stand when exposed to the sun, since these bruchids remain stiff when touched.

2.4 Evaluation of the insecticidal effect of the three powders taken individually or combined on the eggs, larvae and young emerging from *Callosobruchus maculatus*

The experimental set up was the same; the difference made in the assessing toxicities on eggs, larvae and young emerging adults of *C. maculatus* is presented in Table 1.

Table 1: Layout of the days of treatment according to the developing stages of *Callosobruchus maculatus*

State of development	Days of the application of the powder after introduction of adults of *C. maculatus*	Days of observation of the toxicity on 10 seeds taken randomly
Eggs	3 days after spawning	72 hours
Larvae	8 days after infestation	72 hours
Young emerging adults	16 days after infestation	72 hours

100g of healthy cowpeas were initially measured and introduced into jars initially labeled with 4 repetitions. Ten couples of bruchids of 48-hours old were introduced after in each jar.

2.4.1 Impact of the different powders on eggs spawn

Three days after spawning, the bruchids introduced were removed from the contents of each jar. The different jars were then treated with the different powders taken individually or combined (1g, 1.5g and 2g) with 4 repetitions. After 72 hours of oviposition, the toxicity of the product was evaluated by counting the number of living or dead eggs using lens on 10 seeds taken randomly from each jar. The mortality criterion here corresponds to eggs that were dried on the seed coat and were no longer brilliant [23].

2.4.2 Impact of the different powders on larvae

As for the eggs, the experimental steps up were the same with the larvae. The difference here were the day of the application of plant products. Eight days after infestation, the contents of each jar were sieved and cleared of bruchids. These jars were treated with the different powders taken individually or combined (1g, 1.5g and 2g) with 4 repetitions each. After 72h, 10 cowpea seeds taken randomly in each jar were divided into two cotyledons using a razor blade to better observe the larvae because the larvae of *C. maculatus* live in the cotyledons of the seeds. The number of dead larvae were counted. The mortality criterion here corresponds to a larvae that does not move in the open air even when it is touched.

2.4.3 Impact of the different powders on the emergence of *Callosobruchus maculatus*

As for the larvae, sixteen days after infestation, the jars were cleared of dead insects and treated with individual or combined powders (1g, 1.5g and 2g) at 4 replicates each. In each jar, 10 seeds were collected randomly. With the help of a razor blade, the teguments of the circular holes were cleared and the number of young bruchids died inside the hole was counted. The mortality criterion here corresponded to young bruchids that no longer move in the cotyledon or those that emerged and died later.

2.5 Statistical analyzes

The data obtained from the experiments were subjected to one way analysis of variance (ANOVA) using Statgraphic 5.0and then, treatment means were compared by LSD test (Least significant difference) at P = 0. 05.

3. Results

The various tests carried out led to the evaluation of insecticidal effects of the powders of almonds, leaves and bark stem of *B. aegyptiaca* individually or combined on adults, eggs, larvae and young emerging from *C. maculatus*.

3.1 Insecticidal effects of three powders of *Balanites aegyptiaca* taken individually or combined on adults of *Callosobruchus maculatus*

The mortality rates for almond powders, leaves and bark stem of *B. aegyptiaca* on *C. maculatus* adults is shown in Table 2.

Table 2: Insecticide effects of the three powders of *Balanites aegyptiaca* taken individually or combined on adults of *Callosobruchus maculatus*

Balanites aegyptiaca products	**Mortality rate of adults (%)**			
	Quantity used (g)			
	0	**1**	**1.5**	**2**
Almond	2±0.81^{a}	55±1.21^{b}	70±1.33^{c}	80±1.5^{d}
Bark stem	2±0.81^{a}	63±1.19^{b}	75±1.11^{c}	100±0.0^{d}
Leaves	2±0.81^{a}	34±0.95^{b}	48±0.95^{c}	57±0.50^{d}
Combined (Almonds+ Barks+ Leaves)	2±0.81^{a}	68±1.02^{b}	100±0.0^{C}	100±0.0^{C}

In the same line values followed with the same letter are not significantly different at the level 5% LSD test

From these results, adult mortality rates of *C. maculatus* for the 1g, 1.5g, 2g quantities were estimated to be 63%, 75% and 100% for bark stem, respectively. The mortality rates due to almonds were respectively 55%, 70% and 80% for the same quantity of powder used. The mortality rates due to the leaves were 34%, 48% and 57% respectively, still using the same masses of powder. The mortality of *C. maculatus* increases with different quantities of *B. aegyptiaca* powders. The almond and bark stem act more on the mortality of *C. maculatus* and reach their optima at 2g used. On the other hand, the leaves act on the mortality of *C. maculatus* compared to other parts, but leaf mortality was also significant compared to control mortality (2%).
The powder of the bark stem was more effective than that of the almonds which, in turn, was more effective than the leaves in terms of adult mortality *C. maculatus*. Contrary to what has been observed on the adult mortality of *C. maculatus* after the action of the powders taken individually, the action of the powders combined was more effective.
At a dose of 1 g, the mortality due to this mixture was 68% while at the 1.5% dose, mortality was already 100% and the same (100%) are observed with 2g.
In the view of these results, the combination of the insecticidal powders increased the insecticidal power of the formulation and, consequently, reduced the masses of powder used. At 1.5g the combined action of these three powders reaches its optimum and no living bruchids was observed in the jars. Moreover, in the control jar, the mortality rate was low (2%) and the majority of bruchids adult are in the nesting activity. There was a significant difference at the 5% ($p<0.05$) level between the combined powders and the doses used for adult mortality of *C. maculatus*. There was a significant difference at the 5% ($p<0.05$) level of adult mortality of *C. maculatus* depending on the different powders.

3.2 Insecticidal effects of three powders taken individually or combined from *Balanites aegyptiaca* on the eggs of *Callosobruchus maculatus*

The effects of the mortality of the three powders on the eggs of *C. maculatus* is shown in table 3.

Table 3: Insecticidal effects of the three powders of *Balanites aegyptiaca* taken individually or combined on eggs laid by *Callosobruchus maculatus*

***Balanites aegyptiaca* products**	**Mortality rate of eggs (%)**			
	Quantity used (g)			
	0	**1**	**1.5**	**2**
Almond	1±0.57^{a}	55±0.60^{b}	83±0.81^{c}	100±0.0^{d}
Bark stem	1±0.57^{a}	55±0.62^{b}	66±0.57^{c}	80±1.29^{d}
Leaves	1±0.57^{a}	20±1.15^{b}	30±0.96^{c}	56±1.20^{d}
Combined (Almonds+ Barks+ Leaves)	1±0.57^{a}	44.5±0.40^{b}	65.39±0.56^{c}	99.75±0.2^{d}

In the same line values followed with the same letter are not significantly different at the level 5% LSD test

The percentage of egg mortality varied according to the different products of powders. For 1g, 1.5g, 2g the percentages of mortalities increases respectively by 55%, 83% and 100% for almonds. Mortality due to bark powder also increases by 55%, 66% to 80% for the same quantity of powders respectively. The effect due to the leaves powder are 20%, 36% and 56% in the same proportions respectively. This mortality was different from that observed on adults of *C.*

maculatus. Here, almonds were more effective than bark stem, which in turn was more efficient than leaves in terms of egg mortality due to the different powders of *B. aegyptiaca*. The powders of the almond reach their optimum at 2g dose. Compared to the percentage of egg mortality due to the individual powders, the percentage obtained after the combination of the powders also increases but the optimum here was 99.75%, which was not the case for the individual mortality percentage due to almonds. The mixture of the different powders increases the insecticidal power of the different doses but their synergetic action is fast. In the control jar (without treatment), the percentage of natural mortality of the eggs was very low about 1%. There is a significant difference at the 5% level for the mortality of *C. maculatus* eggs between the different treatments and the powders used. This mortality increases according to the quantity of different powders compared to the control jar where the mortality was 1%. There was a significant difference at the 5% ($p<0.05$) level between the combined powders and the different doses to *C. maculatus* eggs.

3.3 Insecticidal effect of three powders taken individually or combined with *Balanites aegyptiaca* on *Callosobruchus maculatus* larvae

The insecticidal effect of the different treatment made on larvae of *C. maculatus* is presented in table 4.

Table 4: Insecticidal effects of the three powders of *Balanites aegyptiaca* taken individually or combined on larvae of *Callosobruchus maculatus*

***Balanites aegyptiaca* products**	**Mortality rate of Larvae (%)**			
	Quantity used (g)			
	0	**1**	**1.5**	**2**
Almonds	1±0.95[a]	55±0.76[b]	62±0.51[c]	80±0.69[c]
Barks stem	1±0.95[a]	47±0.89[b]	54±0.67[c]	66±0.88[d]
Leaves	1±0.95[a]	47±0.50[b]	50±0.71[c]	56±0.93[d]
Combined (Almonds+ Barks+ Leaves)	1±0.95[a]	65.12±0.90[b]	89.57±0.80[c]	100±0.0[d]

In the same line values followed with the same letter are not significantly different at the level 5% LSD test

The analysis of table 4 showed that at doses 1g, 1.5g and 2g the mortalities were 55%, 62% and 80% for almonds. Mortalities from 1g, 1.5g and 2g of barks were 47%, 54% and 66% while those due to leaves were 47%, 50% and 56% respectively in the same proportions. The different percentages of mortalities were increasing as the mass of powder increases. Almonds powders were more effective on larvae than barks powders, which in turn was as effective as leaf powder. Compared to the mortality rate obtained after treatment with the powders taken individually, this rate was too high. The total effectiveness of the combination of the powders has reached the dose of 2g where no larvae survives after the experimental time.

In general, these results show that as the dose of the various powders increases, the insecticidal effect of the new formulation obtained increases also up to 100% of larvicidal effect. It is important to note that at 1.5 g, the percentage of larval mortality due to the combination of powders was already higher than the average percentage of powders taken individually. So, the combination of powders caused a very fast and effective action. In the control jar the natural mortality of the larvae was very low (1%). There was a significant difference between all the treatment made at the 5% level ($p<0.05$).

3.4 Insecticidal effects of three powders taken individually or combined from *Balanites aegyptiaca* on the emergence of *Callosobruchus maculatus*

Table 5 shows the mortality of young bruchids that should emerge after treatment with different masses of *B. aegyptiaca* powders. The insecticidal effects here are consistent with the observed changes in adults' mortality of *C. maculatus.*

Table 5: Insecticide effects of the three powders of *Balanites aegyptiaca* taken individually or combined on emergence of *Callosobruchus maculatus*

***Balanites aegyptiaca* products**	**Mortality rate of Young emerging adults (%)**			
	Quantity used (g)			
	0	**1**	**1.5**	**2**
Almond	0.62±0.57[a]	38±0.90[b]	49±0.5[c]	55±0.25[d]
Bark stem	0.62±0.57[a]	53±0.78[b]	65±0.85[c]	100±0.0[d]
Leaves	0.62±0.57[a]	40±0.61[b]	44±0.48[c]	52±0.85[d]
Combined (Almonds+ Barks+ Leaves)	0.62±0.57[a]	78.87±0.51[b]	98.45±1.4[c]	100±0.0[d]

In the same line values followed with the same letter are not significantly different at the level 5% LSD test

In view of these results the percentage of mortality of young bruchids increased with the mass of powder used and consequently the number of young bruchids that emerge was very low. According to the quantities of 1g, 1.5g and 2g used, the percentages of mortalities were 38%, 49% and 55% for almonds respectively; those of the bark stem were 53%, 63% and 100% in the same proportions; those of leaves were 40%, 43% and 54% always in the same proportions of powder. The insecticidal effect of the bark stem was effective because it reaches its optimum at the dose of 2g where all the young bruchids were ready to emerge, die inside the cowpea grains. The insecticidal effect of almonds was less effective than that of the bark stem. The insecticidal effect of the leaves was significant compared to the control jar where the mortality of young bruchids was less than 1%. There was a significant difference at the 5% level for the mortality of young *C. maculatus* bruchids.

The optimum reached here is 100% at the 2g with bark stem and combination of the three products of *B. aegyptiaca* used. Compared to percentages of mortality due to individual formulations, there was a rapid growth in the percentage of mortality of the young bruchids that emerge from cowpea seeds due to the synergic action of the different powders. There was a significant difference at the 5% ($p<0.05$) level between the different doses and the combination of powders on young bruchids emerging from cowpea seeds.

4. Discussion

The adult's mortality rates for *C. maculatus* obtained 72 hours after infestation were based on the different powders and quantities used. Mortality rates for powders of barks, almonds and leaves were 100%, 80% and 57% respectively at 2g dose. These results were in agreement with those obtained after treatment of cowpea with the oils and powders of *Xylopia aethiopica* [24, 25]. These powders contained monoterpene and sesquiterpene molecules that could be responsible for the insecticidal effect of *C. maculatus* in stock [26, 27, 1]. These different mortalities rates obtained could be also due to differences in the concentration of the active products and / or their chemical nature [28, 29], which varied according to the parts of the plant used [30]. The mortality of *C. maculatus* could be due to these multiple chemical components that would readily diffuse through insect cell membranes [31]. The highest mortalities rates observed due to barks and almonds could be explained by the presence of the important active principle on these two parts of *B. aegyptiaca* than on the leaves. The work of Olofintoye [32] and Pettit *et al*. [33] showed that the active compound in *B. aegyptiaca* powders was saponin. That compound would be more concentrated in almonds and bark. Saponin had an insecticidal effect on adults of *C. maculatus* [32]. The bark powder had active and volatile substances that would act rapidly causing a "knock down" effect on adults of *C. maculatus*.

The mortality rate of eggs laid obtained after treatment with the different powders of leaves, barks and almonds were respectively 56%, 80% and 100%. In contrast to adult mortality, the highest egg mortality rate was due to almonds. These almonds were still rich in oleic acid (37.86%), linoleic acid (35.05%) and palmitic acid (12.80%) [34]. The toxicity of almonds towards eggs could be due in addition to saponin, saturated fatty acid levels that by a lipophilic action migrated inside the seed and even inside the egg [35]. Penetration of oil through the chorion could lead to fragmentation of the chorion following extensive desiccation and abortion [36].

With regard to the mortality of *C. maculatus* larvae, the almonds produced 80%, the bark 66% and the leaves 56%. Once again, the almonds had a high mortality percentage on one of the developmental stages of *C. maculatus*. Almonds therefore had a double effect on the survival of *C. maculatus*. These results were similar to those obtained by Lienard *et al*. [37] which works showed that *Cassia occidentalis* oil had both ovicidal (51%) and larvicidal (72%) effects at a dose of 1g on 20g of cowpea. Almonds had a positive effect on grain conservation as they were factors limiting the proliferation dynamics of cowpea larvae in stocks [37]. In this order, the coating of cowpea seeds with almond oils would make it difficult for neonatal larvae to penetrate grains [38, 39]. Consequently, penetration of the oil into the kernels of cowpea would cause lethal action on *C. maculatus* larvae.

Mortalities rates of young emerging *C. maculatus* for barks, almonds and leaves powders were 100%, 55% and 54%, respectively. The highest percentage obtained with the powders of bark could also have a double action on *C. maculatus* like with almonds. The action of the bark on the grains of cowpea was to trap adults in the pupil cells and lead them to death by asphyxiation [38, 39]. These results were similar to those obtained after the work done on the powders of orange, lemon, cactus, *X. aethiopica*, *P nigrum*, *B. senegalensis*, seeds of *Azadirachta indica*; in this case, powders used lead to the mortality of adults which emerge from *C. maculatus* [25, 38, 40, 41]. Through the holes of emergence, the particles of the powders would have repellent and abrasive effects on the insect's cuticle, and thus accelerate the water losses by evaporation [40]. The results obtained after treatment based on the powders of the bark can also be explained by the concentration of the active ingredient (saponin) at this level than on the other parts of the tree [33]. The work of Pettit *et al*. [33] showed that in addition to saponin 1, the bark also had saponins 2 and 3; these chemical substances were also responsible for the mortality of *C. maculatus*.

The adult mortality percentages of *C. maculatus* obtained after combination of different powders were 68%, 100% and 100% respectively for the 1g, 1.5g and 2g doses. These results were different from those obtained with the powders taken individually. It was important to note that the maximum mortality was obtained with 1.5g. That mortality would result from rapid action of the combined powders. This could be explained by the fact that the combination of these powders would increase the insecticidal effect of the powders and consequently the toxic effect of the powders [25, 27, 42]. The rapid mortality would result from the combined action between the different powders because the work of Singh [31] showed that the combination of powders increased the compounds and the minority compounds were also able to significantly increase the activity of other active compounds.

Petit *et al*. [33] showed that, the almonds of *B. aegyptiaca* were very rich in essential oils (50%), the leaves and the bark possessed essential oils in small quantity. In this line, studies conducted by some authors showed that, the powder alone contained on average 10% of essential oil and that of the combination of powders with essential oils of the same plant increased toxicity towards *C. maculatus* [25]. The combination of plant powders could increase the concentration of the active compounds of the powders and their effective action.

The highest toxicities observed with the different combinations of powders against *C. maculatus* could be due to the combination of several chemical compounds present in the powders [25]. The works of Ngassoum *et al*. [27] also showed that the combination of powders would allow the mixture of volatile compounds, which would promote chemical reactions and therefore the appearance of new toxic molecules or the disappearance of the antagonistic compounds. The ovicidal effect of the combined powders could be explained by the combination of different active molecules present in the powders used which would lead to their strong adhesion and uniform distributions on cowpea grains [42].

The percentages of mortality of the larvae obtained with the combination of the different powder were 65.12%, 89.57% and 100% for the combinations 1g, 1.5g and 2g respectively. These mortality rates were high and differed from the results obtained with individual powders. This could be explained by the fact that the combination of the powders would increase the toxicity of the active molecules which would inhibit the development of the larvae by creating an asphyxiating film on the cuticle with obstruction of the respiratory orifices [38, 43]. This had also been demonstrated on the larvae of *C. maculatus* with the neem oil leading to the disruption of their developmental cycle and consequently with higher mortality [43]. The synergistic effects of these combinations would inhibit the passage of eggs to larvae as shown by work done on the insecticidal activity of *Ocimum gratissimum* and *X. aethiopica* [25].

With regard to the mortality of new emerging adults of *C. maculatus*, 78.87%, 98.45% and 100% emerged respectively at the combined doses 1g, 1.5g and 2g. These results showed an effectiveness of the combinations of the powders compared to the powders taken individually. These results could be explained by the fact that the combination of the powders would increase the toxicity. The combination of powders would increase toxic levels against young pests that should emerge from cowpea seeds [25, 40].

The adulcid, ovicidal and larvicidal effects of the powders of the different combinations or individual products of *B. aegyptiaca* significantly reduced the life stages of *C. maculatus* (P<0.05). In the view of all these results, it appears that the mortality of *C. maculatus* varied according to the different parts of the plant tested and the quantity of applied product.

5. Conclusion

The objective of this study was to investigate the insecticidal effect of almonds, bark and leaves of *B. aegyptiaca* on *C. maculatus*. The various tests carried out with these three powders showed their toxicity towards the life stages of *C. maculatus*. The combination of *B. aegyptiaca* powders showed higher mortality than that of an individual plants powders. The bark and almond powders at 2g per 100g cowpea have shown to be effective and lead to 100% mortality of adults, eggs and young *C. maculatus*, while 100% mortalities were obtained after combination of different powders at a dose of 1.5g. The larvicidal effect of *B. aegyptiaca* is remarkable since the mortality is 80%. In view of these results, it would therefore be advisable to recommend farmers the use of *B. aegyptiaca* powders in the indicated proportions (20g/1000g taken individually or 15g/1000g combined). At the end of this work it appears that *B. aegyptiaca* is an effective insecticidal plant in terms of the parts used.

6. References

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