Effect of solar drying on the biological parameters of the cowpea weevil, *Callosobruchus maculatus* Fab. (Coleoptera-Bruchinae), in Sahelian area.

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**ABSTRACT**

Objective: *Callosobruchus maculatus* Fab. (Coleoptera: Bruchinae) is a major pest of cowpea seeds (*Vigna unguiculata* (L.) Walp) in the Sahelian zone. The grain infestation by this insect pest starts in the field at the beginning of fructification of the plant and continues in storage where the damage can be significant if no protective measures are taken. In order to prevent the damage caused by *C. maculatus* in storage of cowpea, farmers commonly expose the seeds and pods to the sun radiations for several days before storing them. Therefore, the aim of this study is to investigate the impact of sun radiation on the egg laying and development of weevils in general and particularly *C. maculatus*.

Methodology and results: To achieve this goal, experiments were conducted to determine the biological parameters of two batches of this pest respectively exposed to sun radiations and in the laboratory environment. The investigated parameters include longevity, fertility, infertility rate, eggs, development time, larval survival rate and emergence rate. This study results indicated that the different biological parameters studied were significantly affected when the insects were reared under sun radiations. In fact, it appears under this study experimental conditions that sun exposure significantly inhibits egg laying, embryonic development and postembryonic development of *C. maculatus* resulting in complete inhibition of the emergence of the offspring.

Conclusion and application of results: Thus, solar drying seems to be an effective method of preventing weevil damage during cowpea storage.

Keywords: Cowpea; *Callosobruchus maculatus*; solar drying; Sahelian area.

**INTRODUCTION**

Cowpea (*Vigna unguiculata* (L.) Walp.) is a food legume widely cultivated in the world with an estimated 3.3 million tons (FAOSTAT, 2011) of dry seeds of which 64% are produced in Africa. The worldwide-cultivated area is estimated to be more than 12.5 million hectares annually, with about 9.8 million hectares in West Africa. This region is therefore the largest producer and consumer of cowpea in the world (FAOSTAT, 2011). Leguminous food crops in general and cowpea in particular, have been recognized as the best and cheapest solution in the fight against food insecurity mainly because of their high protein content. Moreover, the price of vegetable proteins is two to three times lower than that of animal proteins. Grains of leguminous seeds contain two to three times more protein than cereals,
and contain 24 of the essential amino acids in required proportion for human needs (except for sulphur-containing amino acids). In addition, edible leaves are rich in vitamins and minerals. For these reasons, high interest has been given to the production of leguminous food crops, with preference given to cowpea in Tropical Africa. Despite these tremendous benefits, the post-harvest conservation of cowpea remains a constant challenge for farmers in the Sahelian area. Two coleopteran species, including *Bruchidius atrolineatus* (Pic) and *Callosobruchus maculatus* (F.) are responsible for major loss of cowpea seeds during storage. Adults of these two insect species appear in the farms at the beginning of flowering and fruiting stages. The females gradually lay their eggs on young pods and those ripening (Huignard, 1985; Huignard *et al.*, 1985; Alzouma 1987). During the harvest, the pods or seeds, some of which infested by larvae are stored in traditional barns (Amevoin *et al.*, 2005). The development of these larvae in the cotyledons of the seeds causes significant damage during storage of cowpea (Doumma 1998). Of these two species, *C. maculatus* cause the most significant damage in the storage of this crop because of reproductive diapauses that affects adults of *B. atrolineatus* during the first month of storage. Through its non-flying stage, this species can remain in stockpiles throughout the period of cowpea storage (Ouedraogo *et al.*, 1991, 1996; Sanon *et al.*, 1998). Several generations of reproductive adults overlap in storage depending on the quality of cowpea seeds. Caswell (1961) noticed that in Nigeria, primary infection rate of less than 10% of cowpea seeds by *C. maculatus* was enough to destroy 60 to 70% of the crop a few months later. In Togo (Glitho, 1990) as well as Burkina Faso (Ouedraogo *et al.*, 1996; Sanon *et al.*, 1998), studies have shown that weight losses of cowpea seeds could be higher than 80% after six to seven months of storage. To address this situation, several control measures were developed, including the use of weevil-resistant varieties, biological control, chemical control and traditional control methods (Doumma, 2012). However, in rural areas, lack of financial resources and adequate storage facilities severely limit the effectiveness and usage of these methods. Because of these reasons, farmers have always relied on preventive traditional techniques, including repeated exposure of cowpea to sun radiations before storing them. Moreover, it is common to observe that in Africa farmers expose the pods and seeds of cowpea before storing them in the barns. In this study, we investigate the impact of solar drying of cowpea pods on biological parameters of *C. maculatus*. Results from this study will significantly help to the valorisation of this pest management technique.

**MATERIALS AND METHODS**

**Experimental conditions:** All experiments in this study were conducted on the campus of Abdou Moumouni University of Niamey either in the laboratory environment or under sun exposure. The study was conducted during the months of October, November and December 2013, and it was during this time of the year that farmers exposed the pods and seeds of cowpea in the sun before storing them in the barns. The minimum and maximum temperatures varied respectively from 24.2 °C to 37.8 °C in October and 16.7 °C to 33.3 °C in December (Table 1).

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>October</th>
<th>November</th>
<th>December</th>
</tr>
</thead>
<tbody>
<tr>
<td>max</td>
<td>24.2</td>
<td>19.5</td>
<td>16.7</td>
</tr>
<tr>
<td>min</td>
<td>37.8</td>
<td>36.2</td>
<td>33.3</td>
</tr>
<tr>
<td>Relative humidity (%)</td>
<td>9.7</td>
<td>0.7</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Table 1:** Temperature and relative humidity of the insect collection site

**Origin of the strain of *C. maculatus*:** The strain of *C. maculatus* used in this study experiments was collected from infested cowpea seeds obtained from farmers in the area of Balleymara, located about 100 km north-east of Niamey, Niger. For this purpose, a sample of 6 kg of infested seed was collected and stored in the laboratory.
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in a rectangular Plexiglas box (260×130×77 cm) until the emergence of adults, which were used for subsequent rearing.

**Insect rearing:** For insect rearing, 100 to 150 adults of *C. maculatus* obtained from infested seeds were introduced into a rectangular Plexiglas box (18 cm QUOTE 5.5) containing 150 g of healthy seeds of a variety of cowpea purchased from a local market in the fifth district of Niamey. Healthy seeds meant seeds that were stored in a freezer for at least ten days to eliminate any source of contamination. After 48 h, insects were collected, and the remaining infested seeds were allowed to incubate until the emergence of adults, which were in subsequent experiments.

**Experimental procedures:** In order to study the influence of solar radiation on biological parameters (lifetime, growth parameters), we introduced a couple of *C. maculatus* in a rectangular Plexiglas box (9×6×2 cm) containing 20 healthy seeds of a local variety of cowpea (variety KVX). The experiment was repeated 10 times. The boxes were exposed to the sun radiations during the entire course of the experiment. Boxes prepared under the same conditions as described previously were kept in the laboratory environment as controls. The boxes were daily checked and mortality was recorded. At day 10, after the eggs were laid we counted the fertile and sterile eggs. Sterile eggs differed from fertile egg by the translucent appearance of a seed. The seeds were then kept in their boxes until the emergence of adults. The boxes were daily monitored and the number of emerging adults were recorded and sorted according to their sexes in each box for 14 days. After these experiments, the following parameters are determined:

- The adult life span: The time between emergence and death of the insect
- The number of eggs laid per female during its life time (N).
- The eggs infertility rate: The number of infertile eggs over the total number of eggs.
- Larval survival rate: The number of emerging adults over the total number of fertile eggs
- Emergence rate (ER): The number of emerged adults over the total number of egg laid.
- Development time (T): The time between the laying of an egg on a seed and the emergence of the adult.
- The sex ratio (R) corresponds to the ratio between the number of male and female in the offspring.

** Statistical analysis:** For statistical analysis of the data, the STAT VIEW software. rar. Version 1999 was used to calculate the means (ANOVA or MANCOVA). Pair-wise comparison of the means were performed using Fisher least significant difference (Fisher test, $P=0.05$).

**RESULTS**

**Life span of *C. maculatus* exposed to solar radiation:**
Analysis of the results (Table 2) showed that when insects were exposed to solar radiations, the average life span was 4.5± 0.88 days while for the control group it was 5.40 ± 1.46 days. Thus, insects exposed to the solar radiations died relatively earlier than those kept in the laboratory did. However, statistical analysis of the results showed no significant difference between the life span the insect under the two experimental settings.

**Table 2:** Life span of *C. maculatus* adults depending on the experimental setting.

<table>
<thead>
<tr>
<th></th>
<th>Life span of males (days ± SD)</th>
<th>Life span of females (days ± SD)</th>
<th>Global average life span (days ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun radiation</td>
<td>5.80 ± 1.75a</td>
<td>5.00 ± 1.05a</td>
<td>5.40 ± 1.46a</td>
</tr>
<tr>
<td>Laboratory</td>
<td>4.50 ± 0.85a</td>
<td>4.50 ± 0.97a</td>
<td>4.50 ± 0.88a</td>
</tr>
</tbody>
</table>

Means followed by the same letter in the same column indicate no significant difference (Newman-Keuls test, $\alpha=0.05$).

Furthermore, analysis of adult mortality (Figure 1) indicated that all insects remained alive during the first three days regardless of the experimental condition. Thereafter, insects started to die, and by day 9 there were no survivors in the boxes for each of the two experimental conditions.
**Means followed by the same letter in the same column indicate no significant difference (Newman-Keuls test, α = 0.05).**

**Table 3:** Average life span of *C. maculatus* exposed to solar radiations.

<table>
<thead>
<tr>
<th></th>
<th>Life span of males (days ± SD)</th>
<th>Life span of females (days ± SD)</th>
<th>Global average life span (days ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fed insects and fed and exposed to sun radiations</td>
<td>6.50 ± 3.34 a</td>
<td>8.44 ± 4.50 a</td>
<td>7.421 ± 3.94a</td>
</tr>
<tr>
<td>Unfed insects and exposed to sun radiations</td>
<td>5.80 ± 1.75a</td>
<td>5.00 ± 1.05b</td>
<td>5.40 ± 1.46b</td>
</tr>
</tbody>
</table>

**Effects of solar radiation and sucrose based-diet on life span:** Analysis of the results (Table 3) indicated that the average lifespan of adults of *C. maculatus* could be extended by a sucrose-based diet. This study results indicate that the average lifespan can be extended by two days when insects were fed on sucrose-based diet.

**Eggs laid by adults:** Results (Table 4) showed that the average number of eggs laid by adult *C. maculatus* depends on the environment of exposure of insects. Moreover, the number of eggs laid was two-fold higher for the batch of insects maintained in the laboratory than those exposed to the sun radiations, with respectively 94.60 ± 31.49 and 49.44 ± 34.28 eggs. The average number of sterile eggs per female was also dependent upon the environmental condition of adults' exposure. In fact, this number was more important for insects kept under sun radiations with 28.90 ± 8.02 sterile eggs per female, (64.30 ± 12% infertility rate), as compared to adults maintained in the laboratory where the average number of sterile eggs was only 2.80 ± 1.03 eggs per female, (4.80 ± 02% infertility rate).

**Table 4:** Number of eggs laid and infertility rate depending on the condition of exposure.

<table>
<thead>
<tr>
<th></th>
<th>Number of eggs per female</th>
<th>Number of sterile eggs per female</th>
<th>Infertility rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory</td>
<td>94.60 ± 31.49 a</td>
<td>5.00 ± 2.35 a</td>
<td>4.8 ± 0.02 a</td>
</tr>
<tr>
<td>Sun radiations</td>
<td>49.44 ± 34.28 b</td>
<td>28 ± 9.94 b</td>
<td>58.45 ± 0.13b</td>
</tr>
</tbody>
</table>

Means followed by the same letter in the same column indicate no significant difference (Newman-Keuls test, α = 0.05).
Effect of sun exposure on the development of *C. maculatus*: Analysis of this study results (Table 5) showed that no adult emerged from seeds that were exposed to sun radiations, resulting to almost in no larval survival. Nevertheless, for insects maintained in the laboratory, the larval survival and the emergence rate were relatively high, with respectively 43.6 $\pm$ 0.14 % and 41.1 $\pm$ 0.13. Dissection of the seeds showed in average two dead larvae per seed. The lack of emergence of adults under sun exposure did not allow us to determine the development time under this particular condition.

**Table 5:** Larval survival rate and rate of emergence of adults of *C. maculatus* observed depending on the medium of exposure

<table>
<thead>
<tr>
<th>Sun radiations</th>
<th>Average number of eggs per female</th>
<th>Average number of fertile eggs</th>
<th>Average number of emerged adults</th>
<th>Larval survival rate</th>
<th>Emergence rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory</td>
<td>49.44 ± 34.28 a</td>
<td>0 a</td>
<td>0%</td>
<td>43.6 ± 0.14</td>
<td>41.1 ± 0.13</td>
</tr>
<tr>
<td>Sun laboratory</td>
<td>94.60 ± 31.49 b</td>
<td>89.60 ± 30.29 b</td>
<td>38.50 ± 14.81</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Means followed by the same letter in the same column indicate no significant difference (Newman-Keuls test, $\alpha=0.05$)

**DISCUSSION**

Analysis of the results obtained in this study showed that in this study experimental condition, sun radiations did not have a lethal effect on adults of *C. maculatus*. Moreover, the data did not show significant differences between the insects exposed to sun radiations and those kept in a laboratory environment. These results are different from those obtained by Sembène *et al.* (2006) on groundnut where the authors showed that under extreme temperatures over 33°C, one hour of exposure to sun radiations in a device like Murdock *et al.* (1991) was sufficient to kill all stages of *Caryedon serratus*. The results obtained on the life of *C. maculatus* in this study experimental conditions, can be explained by the relatively moderately varying temperatures observed between 19.5 °C and 36.2 °C during the month of November during the time over which the study was performed. This hypothesis can be confirmed by tests conducted on cowpea by Lale *et al.* (2003) who obtained a total adult mortality of *C. maculatus* and *C. subinnotatus* (Pic) after 6 h of exposure to 50 °C. Furthermore, the solar exposure used in these study experimental conditions does not prevent the contamination of seeds by adult *C. maculatus*. These results can be explained by the nature of the boxes used, that did not allow the insect to escape. Under these conditions, the insect can hide under the seeds during the day and lay their eggs seeds during the night. However, the sun exposure significantly reduces the level of infestation of seeds by *C. maculatus* adults with an average number of eggs laid by adult exposed to the sun radiations significantly lower than that deposited by adults have reared in the laboratory condition. This low level of infestation of seeds by female *C. maculatus* sun radiations can be explained by the behaviour of these insects that prefer to hide under the seeds during daytime instead of laying (Doumma, unpublished data). Furthermore, it appeared from the analysis of the egg laying adults exposed to sun radiations, that this technique inhibits the hatching of deposited eggs leading to a higher high rate of abortions and affect larval development. The resulting effect of the sun radiations led to a complete inhibition of the emergence of the offspring. There was no insect emerging from seeds exposed to sun radiations. This absence of emergence of larvae is not only dependent upon the intensity of the sun radiations that penetrated in the seeds as only two dead larvae were found in these seeds in average. It could also be related to the difficulty encounter by the newly hatched larvae in penetrating the seeds either because of the heat or because of an increase in the hardness of the seeds after the loss of their moisture content. This should result in natural conditions in a significant reduction of the initial infestation rate of the seeds before storing them. Thus, sun radiations , by negatively influencing the growth parameters of *C. maculatus* appears to be an effective preventive measure of seeds store from cowpea weevils in general and *C. maculatus* in particular. The results obtained in this study allow the explanation of the observations of Doumma (2007) showing that exposure of cowpea pods to sun radiations for up to four weeks considerably limits the evolution of populations of weevils and their parasitoids. The effect of this method on the various biological parameters of *C. maculatus* is related to a reduction of the water content of the seed; According
to Cruz and al. (1988) when the water content of the seeds is very low, the eggs hatching is inhibited, and the larvae fail to develop. This method also promotes the departure of adult weevils that cannot tolerate extreme heat or intense sunlight (in stock, insects are often confined in darker areas).

REFERENCES


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