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The Impact of Agro-Ecological Variation on Biological Parameters of *Bruchidius atrolineatus* Pic (Coleoptera-Chrysomelidae-Bruchinae)

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Abstract

In this study, the biological parameters of two *B. atrolineatus* strains originated from two different agro-ecological areas of Niger are examined. The analysis of the adult lifetime showed that *B. atrolineatus* strain of the Sahelo-Sudanese area lived longer (7.58 ± 2.19 days) than that of the Sahelian area (7.44 ± 1.39 days). Furthermore, males lived longer than females regardless of the strain origin. The egg laying activity showed that the eggs laid number was not statistically different according to the two areas. But it appeared that more than 94% of the eggs were laid in the first four days of cowpea seed infestation. The larvae survival rate and the rate of emergence also varied according to the geographical strain origin. There were few data recorded in Sahelian area where nearly 30% of the larvae did not reach adult stage. In the Sahelo-Sudanese area, less than 4% of the hatched larvae reached the adult stage. The sex-ratio also varied according to the geographic strain origins. It was in favor of males in the Sahelian area and was in favor of females in the Sahelo-Sudanese area.

Keywords

Cowpea, Bruchids, Agro-Ecological, Biological Parameters, Niger

Subject Areas: **Entomology**

1. Introduction

Cowpea, *Vigna unguiculata* (L.) Walp., is a leguminous plant that plays an important role in people's diet in

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Africa and in almost all tropical regions. The seeds of this plant represent an important source of protein in sub-Saharan countries, and a substitute for proteins of animal origin. Furthermore, cowpea is an important source of income for farmers in West Africa. However, all developmental stages of cowpea are under constant attack by many pest species [1], most of which belong to the subfamily Bruchidae. In Niger, cowpea damage is principally caused by two species of weevils including *Bruchidius atrolineatus* Pic. and *Callosobruchus maculatus* Fab. The adults of these two species infest cowpea plant as early as the beginning of flowering season and continue during the harvest and storage. Females of bruchids lay their eggs on the surface of the pods as soon as they begin to form [1], and once the eggs hatch, the larvae penetrate the seeds where they find nutritious substances to continue their post-embryonic development. The larvae and pupae become already present active. During the early phase of storage of cowpea pods and seeds, the level of infestation caused by these pests is generally less than 5% [2]. This rate can increase to 30% in just one month of storage, and 80% to 100% within 5 to 6 months if no appropriate control measures are taken [3]-[5]. Among the two species of weevil, *Bruchidius atrolineatus* is the species that is primarily responsible for damage in the field and during the storage of cowpea. In fact, our previous studies in the region of Niamey, Niger, have shown that 80% to 90% of the harvested cowpea pods were infested with *B. atrolineatus* eggs. Approximately 90% of the bruchids emerging from these pods during the first three months of storage belong to this species [6] [7]. Damaged seeds can be completely hollowed out by feeding larvae, causing a severe loss of seed weight, nutrition, germination potential, and thereby the commercial value of the commodity [8].

In order to reduce the damage caused by cowpea weevils, several control measures have been developed and tested. These methods include the use of insecticides, repellent plants, essential oils, ash and many others [9]-[12]. However, it is clearly accepted that a deep understanding of the bio-ecology of the pest species is critical for the success of any control measure. The bio-ecological parameters were greatly depended on the climatic factors that influenced the development and reproduction of the pest species [13]. This is particularly important for the largest country like Niger with four different agro-ecological areas. The objective of the present study is to characterize the *B. atrolineatus* strain of Niger by determining its biological parameters such as life span, fertility, development time and survival rate in different developmental stages.

2. Materials and Methods

2.1. Materials

The strains of *B. atrolineatus* used in this study were taken from the cowpea seeds and pods collected from producers of the locality of Gaya (11˚53′3 N and 3˚26′57 E, Sahelo-Sudanese area, Dosso region), and the region of Niamey (13˚30′49 N and 2˚6′35 E, Sahelian area). The characteristics of these two localities are indicated in **Table 1**. The infested cowpea seeds (6 to 9 kg) were collected from producers in each of two localities. These samples were transported to the laboratory and stored in parallelepiped plexiglas bottles of size 260 × 130 × 77 cm. The infested seeds were kept there until adult insects emerged and then would be reared and used for the experiments.

2.2. Methods

After the emergence, the content of each bottle was sieved and the adult's bruchids were collected and placed in clean bottles containing 100 to 120 g of non infested seeds for laying eggs. The bruchids were placed in bottles containing the seeds from the same locality, where it's were originally collected. After 48 h, the insects were removed from the bottles and the infested grains were kept again until emergence. The emerging adults were then collected and used for analysis of bio-ecological parameters.

Table 1. Agro-climatic references of the localities studied.

Localities	Agro-climatic zone	Rainfall	Geographical coordinates
Niamey	Sahelian zone	400 à 600 mm	13˚30'49″N et 2˚6'35″E
Gaya	Sahelo-Sudanese zone	Plus de 600 mm	11˚53'3N et 3˚26'57 E

Source: AGRHYMET (NIGER).

2.2.1. Experimental Procedure

The experiment consisted to put a couple of *B. atrolineatus* in a petri dish containing 10 healthy seeds of cowpea (*Vigna unguiculata L.* Walp). Daily, the seeds are replaced by new seeds in the petri dishes, until the complete death of insects.. After 10 days, the infested seeds were analyzed for the number of laid eggs and kept until adult emergence. This experiment was repeated 20 times for each of the two strains. Different parameters of *B. atrolineatus* were established including:

- Adults longevity: number of days from emergence to death.
- The number of eggs laid by females (N): the total eggs laid on the seeds during the lifespan of a female.
- The developmental time: The number of days between the laying of an egg and the emergence of adult from that egg.
- The fertility rate: The ratio between the number of fertile eggs and the total number of eggs laid.
- Larval survival rate (S): The ratio between the total number of emerged adults and the total number of fertile eggs multiplied by 100.
- Emergence rate: The ratio between the total number of emerged adults and the total number of eggs laid.
- The sex-ratio: The ratio of male and female in the offspring.

2.2.2. Embryonic Development Time

To determine the embryonic development time, one cowpea seed containing only one newly laid egg was introduced in a petri dish for each of the strains. The egg was observed daily until the 10^{th} day of experiment and the number of hatched eggs was recorded every day. For each strain the experiment was repeated 50 times. Sterile eggs differ from the fertile eggs by their translucent appearance.

2.3. Data Analysis

The STAT VIEW software. rar. Version 1999 was used for data analysis. The variance analysis (ANOVA or MANCOVA) was computed. The pairwise comparison of the means was performed using Fisher procedure at 5% significance level.

3. Results

3.1. Longevity of *Bruchidius atrolineatus* Adults

The statistical analysis showed that the Sahelo-Sudanese strain of B. *atrolineatus* lived relatively longer (7.58 ± 2.19 days) than the Sahelian strain (7.44 ± 1.39 days). The longevity of females of the two bioclimatic areas was not statistically different. However, the longevity of male varied depending on the geographic origin of the strain. Our results also showed that the males of the Sahelo-Sudanese (Gaya) strain lived longer (7.65 days) than those of the Sahelian area (Niamey) (7.47 days). For both strains, males lived longer than females (**Table 2**).

3.2. Survival Curve of *B. atrolineatus* Based on Agro-Climatic Area

During the first two days of the experiment, all the adults of *B. atrolineatus* of the different strains remained alive (**Figure 1**). The beetles started to die at the third day (J3) for the Sahelian area strain and at the fourth day (J4) for that of the Sahelo-Sudanese strain. The adult mortality was observed every day from the third day (J3) for Sahelian area strain and forth day (J4) for those of sahelo-Sudanese until all the insects were deaden. This mortality was more spread for Sahelo-Sudanese strain for whom some adults still alive until day12 (J12), whereas no survivor was found after 10 days (J10) for the adults of the Sahelian strain.

Table 2. Longevity of *B. atrolineatus* based on agro-climatic zones.

Agro-climatic areas	Average longevity of female (days)	Average longevity of male (days)	Average longevity (days)
Sahelian area	7.42 ± 1.34a	7.47 ± 1.46a	7.44 ± 1.39a
Sahelo-Sudanese area	7.52 ± 2.08a	7.65 ± 1.63b	7.58 ± 2.19b

NB: Means followed by the same letter(s) are not significantly different at the 5% level (*Test of Newman and Keuls*).

3.3. Eggs Laying Activity

The mean of eggs laid by female of *B. atrolineatus* from the two agro-ecological areas was presented in **Table 3**. The results showed that for both strain, there was no significant variation in realized fecundity and egg fertility ((P = 0.847). The mean of eggs laid by female was 35.50 ± 15.42 eggs for Sahelo-Sudanese strain and 34.93 ± 17.25 eggs for Sahelian strain. Egg fertility rate recorded for the two strains was very important and higher than 94%.

3.4. Daily Evolution of *B. atrolineatus* Fecundity Based on Agro-Ecological Areas

For both strains, females began to oviposit as early as the first day of experiment (**Figure 2**). However, more than 94% of eggs were laid during the first four days of *B. atrolineatus* life. Thus it appeared that more than 98% and 94% of eggs were laid during the first four days of the infestation for Sahelian and Sahelo-Sudanese strain, respectively. The highest number of eggs laid by females was observed at the second day (J2) for the strain of the Sahelo-Sudanese area and third day (J3) for the Sahelian strain (**Table 4**).

3.5. Larval Survival and Emergence Rates

The results reported in **Table 5** indicated the larval survival and adults' emergence rate observed in the two agro-ecological areas. The analysis of these results showed that more larvae survived in the Sahelo-Sudanese area (96.43%) than in the Sahelian area (70.10%). Moreover, larval mortality rate was relatively higher in the Sahelian area where a mortality rate of 30% was recorded. This rate was higher than the mortality observed in the Sahelo-Sudanrese area where the larval mortality was less than 4%. These important variations in the larval survival rate resulted a low emergence rate of *B. atrolineatus* adults in Sahelian area where adults' emergence rate of 66.47% was recorded.

3.6. Embryonic and Larvae Developmental Time

For both strains, there was no significant difference in the embryonic developmental time. The eggs laid on the seeds gave rise to L1 larval after 5.06 ± 1.07 and 4.72 ± 1.06 days for the Sahelian and Sahelo-Sudanrese strains,

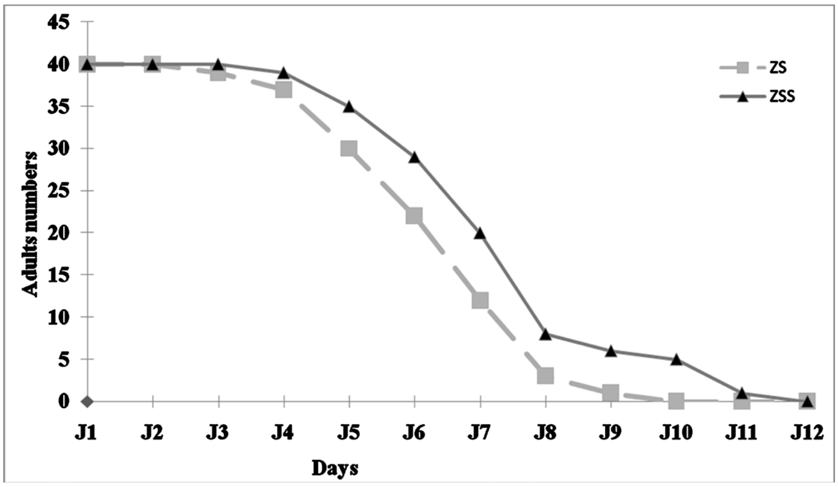

Figure 1. Survival curve of *B. atrolineatus* based on agro-climatic area. ZS: Sahelian zone, ZSS: Sahelo-sudanese zone.

Table 3. Average number of egg laid, hatched and fertility rate of *B. atrolineatus* base on agro-ecological origin.

Agro-climatic areas	Average number of eggs/female	Average number of hatched eggs/female	Egg fertility rate%
Sahelian zone	34.93 ± 17.25a	33.12 ± 16.29a	94.81%
Sahelo-Sudanese zone	35.50 ± 15.42a	33.66 ± 15.25a	94.81%

N.B: Means followed by the same letter(s) are not significantly different at the 5% level (*Test of Newman and Keuls*).

respectively. However, the average larvae developmental time was significantly higher for the Sahelian strain (34.64 ± 3.00 days) than for Sahelo-Sudanrese strain (32.73 ± 3.73 days) (**Table 6**).

3.7. Sex Ratio Variation

The *B. atrolineatus* sex ratio varied according to the geographical origin of the strains. Thus, the analysis of the results indicated that the sex ratio was in favor of males (under 50%) in the Sahelian area, while more females (over 50%) were produced in sahelo-Sudanese area (**Table 7**).

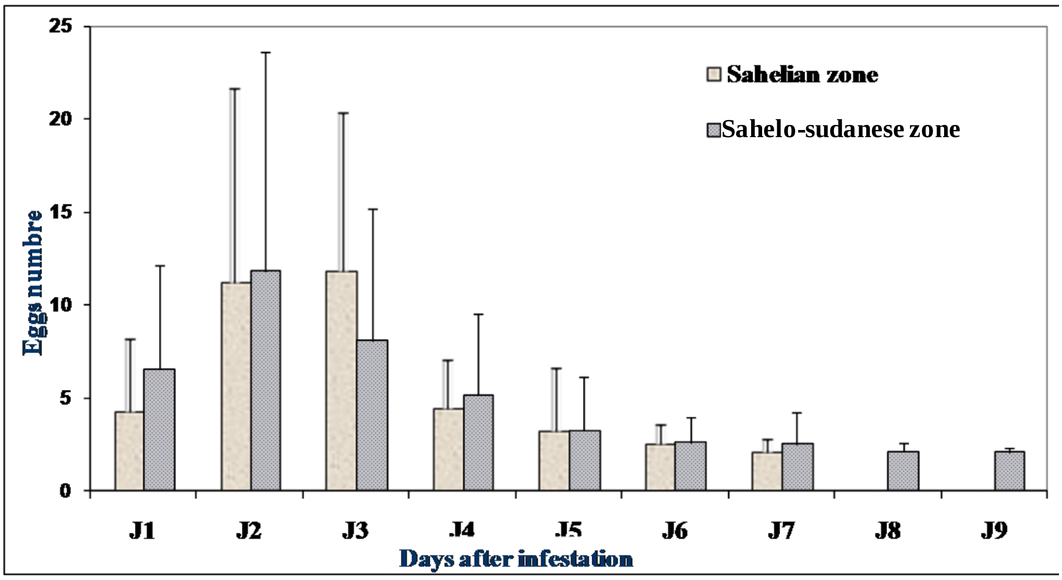

Figure 2. Daily evolution of the number of eggs laid by *B. atrolineatus* female according to agroclimatic zones.

Table 4. Percentage of eggs laid during the life span of *B. atrolineatus* female.

Strain origin	First day	First two days	First three days	First four days	Remaining time of the experiment
Sahelian area	46.49	84.30	90.29	98.14	1.86
Sahelo-Sudanese area	51.24	76.35	89.42	94.61	5.39

Table 5. Embryonic and larval development periods observed for the two strains of *B. atrolineatus.*

Strain origin	Embryonic developmental time (days)	Larvae developmental time (days)
Sahelian zone	5.06 ± 1.07a	34.64 ± 3.00a
Sahelo-Sudanese area	4.72 ± 1.06a	32.73 ± 3.73b

N.B: Means followed by the same letter(s) are not significantly different at the 5% level (*Test of Newman and Keuls*).

Table 6. Larvae survival rate and emergence rate observed in the two agro-ecological zones.

Strain origin	Average number of eggs/female	Average number of hatched eggs/females	Average number of adults	Larvae survival rate	Emergence rate
Sahelian Zone	34.93 ± 17.25a	33.12 ± 16.29a	23.22 ± 10.23a	70.10%	66.47%
Sahelo-Sudanese zone	35.50 ± 15.42a	33.66 ± 15.25a	32.46 ± 9.27b	96.43%	91.43%

N.B: Means followed by the same letter(s) are not significantly different at the 5% level (*Test of Newman and Keuls*).

Table 7. Sex-ratio of *B. atrolineatus* in the two agro-ecological zones.

Agro-ecological zones	Number of emerged adults	Number of emerged females	Sex-ratio en %
Sahelian Zone	23.22 ± 10.23a	10.57 ± 6.16a	45.52
Sahelo-Sudanese zone	32.46 ± 9.27b	23.23 ± 8.05b	71.56

N.B: Means followed by the same letter(s) are not significantly different at the 5% level (*Test of Newman and Keuls*).

4. Discussion

The most important finding of this study is that populations of *B. atrolineatus* originating from within a relatively small geographical area, in Niger, have been found to exhibit measurable and significant differences in various biological traits associated with developmental performance. The analysis of the adult life time showed that *B. atrolineatus* strain of the Sahelo-Sudanese area lived longer (7.58 ± 2.19 days) than those of the Sahelian area (7.44 ± 1.39 days). Comparatively, longevity of the sympatric species of *B. atrolineatus* in cowpea storage, *Callosobruchus maculatus* live was less than 6 days regardless of the agro-climatic zone [13]. The results showed that the males lived longer than females regardless of the strain origin. These results can be explained by the intensive egg laying activity of females which involved a significant reduction of their longevity. This may be caused by the massive use of nutrients in the development and maturation of ovocyte. Furthermore, it has been suggested that mating activity significantly affect female lifetime [5], in animal kingdom. The cost of reproduction has been extensively studied in many insects [14]-[17]. The trade-off between mating and longevity has also been reported for the cowpea bruchid [18]. A commonly accepted explanation for the negative impact was that mating may divert limited resources to activities associated with reproduction such as courtship, copulation, egg production and sperm donation, thereby reducing resources available for somatic maintenance [15] [17]-[19].

The analysis of the egg laying activity showed that more than 94% of the eggs were laid in the first four days of cowpea seed infestation as observed on *C. subinnotatus* by [20] and on C. *maculatus* by [13]. The larvae survival rate and the rate of emergence also varied according to the geographical origin of the strain. There were few data recorded in Sahelian area where nearly 30% of the larvae did not reach adult stage. Similarly, in the Sahelo-Sudanese area less than 4% of the hatched larvae reached the adult stage. The higher mortality rate observed in Sahelian area, suggested that adults originating from this geographical area seemed to enter in diapause earlier than those of the Sahelo-Sudanese area. Moreover, many authors indicated that *B. atrolineatus* adults were affected by reproductive diapause induced during the development of the insect [21] [22]. The sex-ratio also varied according to the geographic origin of the strains. It was in favor of males in the Sahelian area and was in as of females in the Sahelo-Sudanese area. These results were different with those observed on *Callosobruchus maculatus* where the sex-ratio was in favor of the females in Sahelian area (Niamey) [13]. Differences in biological traits among populations collected from different countries and/or continents have already been reported by numerous authors. For instance, [23] reported a significant variation in parameters associated with development and survival among three strains of *C. maculatus* from Brazil, the Yemen Arab Republic and Nigeria, infesting cowpeas. [24] observed a significant genetic differences in the preference of cowpeas and other legumes among strains of *C. maculatus* originated from different countries, and also indicated an inter-strains differences in fecundity in this species [24]. Differences observed among populations could have arisen via a number of processes acting on the parent populations from which there were originated. It should be explained by the long-term adaptation to the local environmental and/or storage conditions occurring across a country [25]. According to these authors, population differences could also arise because of adaptation to different host varieties or species occurring in different locations. Excluding egg fertility and embryonic development period, most of the other measured parameters, including life span, fecundity, larval development, and larval mortality showed significant differences among populations on the two strains.

5. Conclusion

The comparison of biological parameters of the strains of *B. atrolineatus* originated from two different agro-ecological areas of Niger shows that the reproductive capacity of this pest is very important under all the climate conditions with only slight variations, depending on the origin of the strains studied. These results are of great importance in the development of integrated pest management strategy against this species.

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