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Variations in body size and some life history traits among *Callosobruchus maculatus* (Fab.) (Coleoptera: Chrysomelidae, Bruchinae) strains from different areas in three countries of West Africa

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Abstract
In West Africa, *Callosobruchus maculatus* is the main pest of stored cowpeas (*Vigna unguiculata* Walp.). An effective control of this pest depends on a good knowledge of its population growth ability and the diversity of strains in cowpea crop areas. In this study strains from Dakar (Senegal), Niamey (Niger) and five localities of Burkina Faso were collected and compared in similar laboratory conditions. We found that body size and life history traits slightly varied among the strains studied. In general, females from the Dakar strain were smaller and had lower intrinsic rate of natural increase. Specifically the small size of Dakar females seems to have caused a decrease in lifespan and fecundity coupled with an increase of development duration. Such variations may also occurred to a lesser extent among populations from the same country as it was noticed for Burkina strains. These results show that despite the apparent homogeneity of *C. maculatus* populations in West Africa, morphological and biological diversity exists and should be better understood and integrated for optimal pest control methods.

Keywords: *Callosobruchus maculatus* strains, body size, life-history traits, biotic potential, environment variations, West Africa

1. Introduction

Cowpea, *Vigna unguiculata* (L.) Walp (Fabaceae) is the main food legume grown in West Africa a major production area of this crop [1]. Cowpea plays an important socio-economic role in the developing countries, because in addition to filling the nutritional deficiencies in protein, it is also a source of income for farmers [2, 3, 4]. However this important legume is subject to attack by the bruchid beetle *Callosobruchus maculatus* Fab. during the post-harvest storage of cowpeas and causing substantial losses each year.

Proper storage of cowpeas ensures the availability of food resources as the crop production is most of the time seasonal. Similarly a good and longtime protection of stored cowpeas allow producers to improve their incomes as prices gradually increase from the harvest period [5]. Therefore cowpea is regarded as a promising sector to alleviate poverty among small scale farmers. During the last decade many studies have intensively focused on the assessment and development of cowpea storage methods in West Africa including several alternative control measures [6-8] as a response to so many hazards linked to insecticide applications [9]. Today triple bagging of cowpeas known as PICS bags developed by the Purdue Improved Cowpea Storage project (www.ag.purdue.edu/ipia/pics) is a very effective hermetic storage method for cowpeas and several other crops [7, 10, 11]. Therefore it is being actively extended in several areas of the world. However insects do not react the same way and the efficiency of a method may be related to the insect strain considered. A good pest control strategy should be based on an understanding of the diversity of these insects and their biotic potential in their habitats [12]. It is in the same direction as an author [13] proposed that the four basic hierarchical ecological scales, i. e. individual, populations, communities and ecosystems, should serve as the template for IPM integration. Moreover ccombining morphology with life history traits could give critical indications for successful comparison of an insect species populations living in different agroecological areas [14-16].

In this study we focused on *C. maculatus* populations evolving in different areas of cowpea production in West Africa to investigate whether this insect individuals from different ecological areas were morphologically and biologically similar or not. Therefore strains from different climatic areas, in Dakar (Senegal), Niamey (Niger) and in five localities of Burkina Faso were collected and compared in similar laboratory conditions based on their morphometry and some life history traits.

2. Material and methods

2.1 Origin of *C. maculatus* strains

At the beginning of the study in October 2012 *C. maculatus* strains were collected from seven (07) sites in West Africa (Fig. 1), including five (05) in Burkina Faso (Houndé, Bobo-Dioulasso, Tenkodogo, Kombissiri and Dori), one (01) in Niger (Niamey) and one (01) in Senegal (Dakar).

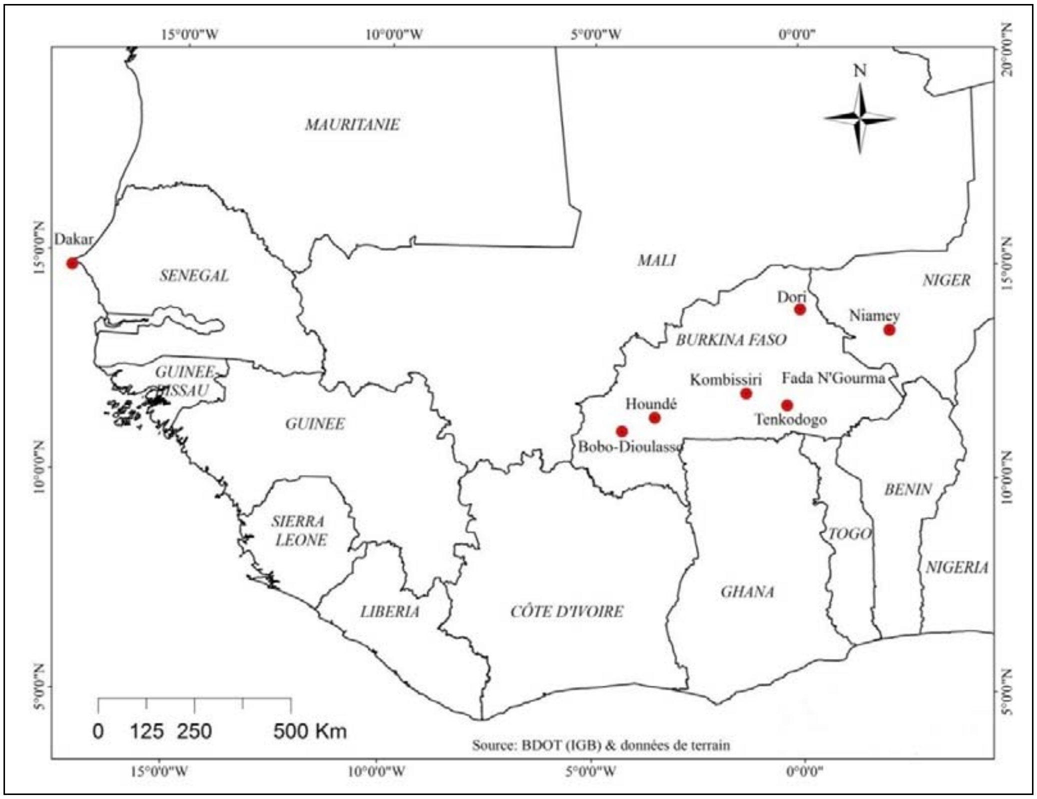

Fig 1: Origin of *C. maculatus* strains studied. Red points represent sampling localities in several areas of cowpea production in West Africa.

These localities belong to four (04) different climatic zones including the Sahel (Niamey and Dori), the Sahelo-sudanian (Dakar), the South-sudanian (Bobo-Dioulasso and Houndé) and the North-Sudanian (Tenkodogo and Kombissiri) zones. The average temperatures vary among the localities between 24 and 30.5 °C, the relative humidity was 41.5-70% and the mean annual rainfall ranged 545-1099.9 mm (Table 1).

Table 1: Climatic parameters of the different areas of *C. maculatus* origin in three countries of West Africa

Localities	Countries	Average temperature (° C)	Relative Humidity (%)	Rainfall (mm)	Climate Zone
Niamey	Niger	30.5	41.5	543.5	Sahelian
Dakar	Senegal	24	70	500-600	Sahelo-Sudanian
Dori	Burkina Faso	29.9	43.3	545	Sahelian
Bobo-Dioulasso		27.6	56.25	1099.9	South-Sudanian
Houndé		27.6	56.3	1099.9	South-Sudanian
Tenkodogo		28.3	52.9	773.6	North-Sudanian
Kombissiri		28.8	48.8	744.71	North-Sudanian

2.2 Collection of *C. maculatus* strains

To set up various *C. maculatus* strains, cowpea was sampled using the same methodology in each of the above mentioned localities. Samples of either 1kg of cowpea pods or 500 g of seeds were taken with five farmers in each locality at the beginning of post-harvest storage period in October 2012. Each sample was labeled and packaged in cloth bags (40 x 20cm) and forwarded to the Laboratory of Fundamental and Applied Entomology. The pods/seeds from each sampling zone were separately monitor until insect emergence. Then, newly emerging insects were used for continuous rearing and laboratory experiments from January to May 2013.

2.3 Study environments

All experiments and rearing were conducted in the Laboratory of Fundamental and Applied Entomology located at the University Ouaga I in Burkina Faso under controlled conditions in an incubator at the average temperature of 32±0.1 °C and an average relative humidity of 36 ± 1%.

2.4 Source of the cowpea seeds and insect rearing in laboratory

Cowpea seeds of the landrace variety *Moussa* previously described [7] were used to maintain each *C. maculatus* strain into laboratory. Prior to their use cowpea seeds were examined and sorted to eliminate those carrying bruchid eggs or immature instars, and those that were perforated. Sorted seeds were then placed during 2 weeks in a freezer at a temperature of -18 °C in order to destroy any initial infestation. For insect rearing, fifty (50) pairs of each strain were introduced with 200g of cleaned seeds in Plexiglas boxes (L = 17 cm; l = 11 cm and h = 4 cm) for 24 hours. At the end of the contact time, insects were removed and infested seeds left in the incubator until the emergence of a new insect generation used either for various experiments or up keeping the strains from the same procedure.

2.5 Determining body size variations among *C. maculatus* strains

Two (2) batches of 50 males and females of each strain were individually placed in Petri dishes and asleep in the freezer (-18 °C) for 30 minutes. Then individual insect were directly measured with a caliper to determine the overall body size ranging from head to pygidium. The comparison was then made between same-sex insects from different strains.

2.6 Determining life history parameters for *C maculatus* strains

Twenty (20) pairs of newly emerged *C. maculatus* were separately introduced in Petri dishes containing each 20 healthy seeds, for each strain and for 24h. After this time period, insects were removed and the infested seeds were placed in rearing conditions and monitored. The cowpea seeds were then renewed each day with the same pair of insects until the female died which ends the experiment. Each infested seed batch was carefully examined 7 days after infestation using a microscope, to count the eggs laid on the seeds and the hatched eggs. Infested seeds allowed the emergence of a new generation of insect followed from the first emergence date and ending 2 weeks later. Data recorded during the experiment were used to determine the following parameters:

- Female lifespan (L)
- The mean number of eggs laid per female (N)
- Larval survival rate (S) is the percentage of insects emerged relative to the total number of hatched eggs;
- The development duration (T): mean time between egg laying and the emergence of adults
- The intrinsic rate of natural increase (r) is a more synthetic parameter that incorporates the above cited ones. It is estimated using the following formula (Giga and Smith,1983):

$$r = \frac{\ln(NS)}{T + {}^{1}/_{2L}}$$; With *ln*= neperian logarithm

2.7 Statistical analysis

Data were submitted to ANOVA and when the probabilities indicated significant differences, means were separated by the Student Newman-keuls multiple comparison test using SAS software 9.1 version. In all the cases means were considered as different when the test provided discrimination at the 5% level.

3. Results

3.1 Body size variations among *C. maculatus* strains

Three body size levels were observed whatever the sex (Figures 2 and 3). Males and females of the Dakar (Senegal) strain were smaller than the others, while insects from the Bobo-Dioulasso (Burkina Faso) strain exhibited intermediate size. The strains from the other localities of Burkina Faso and from Niger (Niamey) seemed to have a similar body size both for males and females. Females of all the strains compared were significantly larger than males ($P<0.05$).

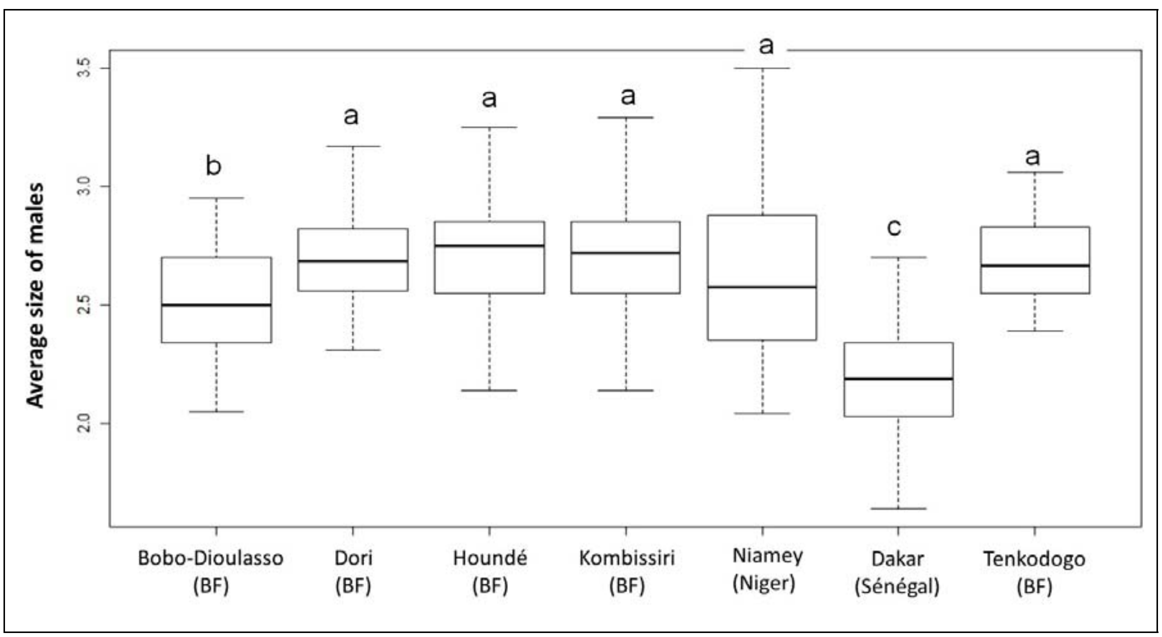

Fig 2: Variation of mean size (± SD mm) in *C. maculatus* males from different strains (localities) in West Africa. BF = Burkina Faso.

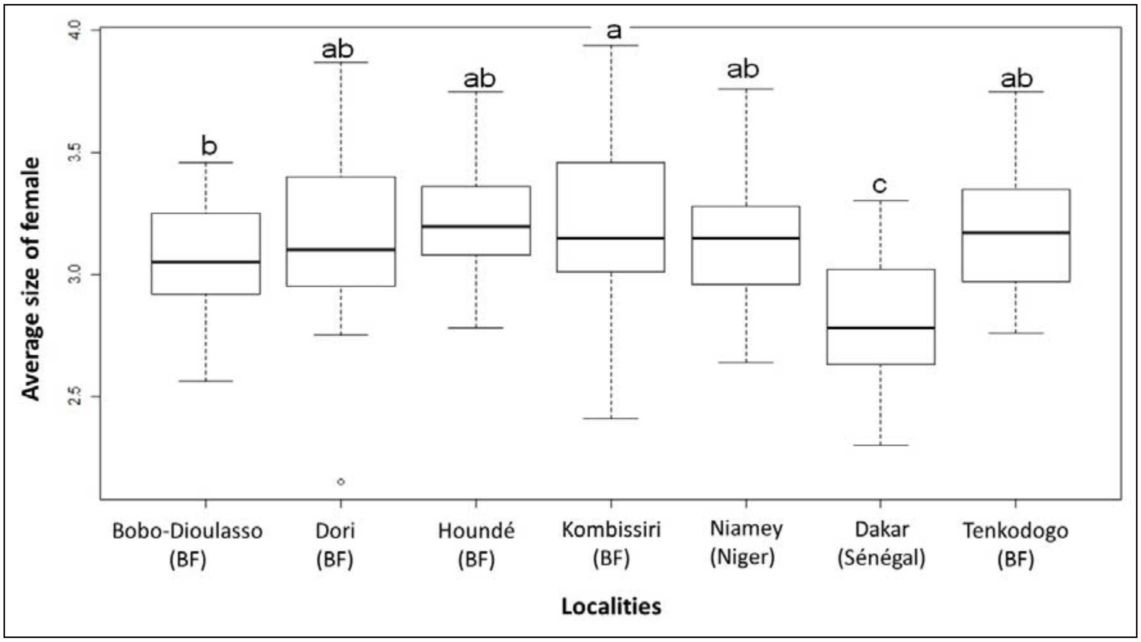

Fig 3: Variation of mean size (± SD mm) in *C. maculatus* females from different strains (localities) in West Africa. BF = Burkina Faso.

3.2 Comparison of life history traits for *C. maculatus* strains

All the results are shown in Table 2.

Table 2: Comparative life history traits among various *C. maculatus* strains from West Africa.

Origin of *C. maculatus* strains	Female lifespan (days)	Number of eggs laid per female	Larval survival (%)	Development duration (days)	Intrinsic rate of natural increase (r) (per day)
Bobo-Dioulasso (BF)	3.3± 0.79 b*	38.94 ± 3.05 ab	79.6 ± 0.09 ab	21.8 ± 1.61 a	0.154 ± 0.02 ab
Dori (BF)	3.9 ± 0.69 ab	48.93 ± 1.98 a	76.6 ± 0.12 b	19.9 ± 1.21 b	0.157 ± 0.03 ab
Houndé (BF)	4.05 ± 0.76 a	40.69 ± 3.89 ab	88.1 ± 0.09 a	20.70 ± 1.38 b	0.156 ± 0.02 ab
Kombissiri (BF)	3.95 ± 0.89 ab	47.47 ± 3.11 ab	83.6 ± 0.10 ab	20.45 ± 1.05 b	0.164 ± 0.02 a
Niamey (Niger)	3.95 ± 0.69 ab	47.50 ± 1.09 ab	77.7 ± 0.10 b	20.20 ± 1.28 b	0.162 ± 0.02 a
Dakar (Senegal)	3.25 ± 0.44 b	35.73 ± 2.13 c	75.4 ± 0.08 b	22.45 ± 1.15 a	0.144 ± 0.01b
Tenkodogo (BF)	3.80 ± 0.61 ab	50.78 ± 4.92 a	82 ± 0.11 ab	19.65 ± 0.93 b	0.160 ± 0.02 ab

* Means (±SD) within column followed by different letters are significantly different according to the Newman-Keuls multiple comparison test. *P<0.05*. BF = Burkina Faso.

3.2.1 Female lifespan

Female lifespan significantly varied among the strains compared. Females from Houndé strain lived longer than females of the other strains whereas Dakar and Bobo-Dioulasso strains exhibited the shorter lifespan.

3.2.2 The mean number of eggs laid by females

Females from Dakar (Senegal) strain laid fewer eggs than those of other areas. On the other hand there was no significant difference between the number of eggs laid by females of Niamey (Niger) and Burkina Faso strains whatever the locality of insect origin.

3.2.3 Larval survival

Most of the Burkina Faso strains specifically that from Houndé, had better survival than those from Dakar (Senegal), Niamey (Niger) and Dori (Burkina Faso). In all cases survival rates were higher than 75%.

3.2.4 Development duration

The *C. maculatus* development duration was higher in Dakar and Bobo-Dioulasso strains and significantly differed from the durations obtained in all the other strains. In the experiment conditions the development duration varied from 19.65 (Tenkodogo strain) to 22.45 (Dakar strain) days.

3.2.5 Intrinsic rate of natural increase

Regarding the biotic potential three groups were distinguished including (1) the higher potential group for Kombissiri (Burkina Faso) and Niamey (Niger) strains, (2) the medium potential group with all the other Burkina Faso strains and (3) the lower biotic potential in the Dakar (Senegal) strain.

4. Discussion

In this study several strains originating from various cowpea growing ecological areas of West Africa were compared in the same laboratory conditions. Thus, we can assume that any differences observed in these strains come from their origin and their intrinsic factors. The results showed that despite an apparent homogeneity of *C. maculatus* populations in all areas of cowpea production in West Africa [17-19] there may be differences among individuals in relation with their origin. Morphological comparison by body size measurement revealed a significant reduction in the size of *C. maculatus* individuals belonging to the Dakar strain in comparison to strains from Burkina Faso and Niger except insects from Bobo-Dioulasso in Burkina Faso that exhibited intermediate size. Thus it seems that within the same country a relative morphological variation can be observed in relation with the zone of insect origin. This unexpected result should be confirmed by extending the study to several strains from different agro-ecological zones of both Senegal and Niger.

Nevertheless the observed results are probably related to the variations in climatic conditions of the areas of insect origin. It appears that the climatic conditions of Dakar are quite different from those of the localities of Burkina Faso and Niger where the strains came from. While Dakar is ranked in Sahelo-Sudanian climatic zone, the localities of Burkina Faso and Niger belong to the Sahelian, south- and north- Sudanian zones. Then main climatic factors that significantly vary are temperature and air relative humidity in correlation with rainfall. Several studies demonstrated the role of climatic conditions and host plant on insect morphology and specifically body size [20-24]. However some authors [25] studying geographic variation in body size of the weevil *Stator limbatus* concluded that clinal variation in three factors likely explains the cline in size: host plant seed size, moisture (humidity), and seasonality (within-year variation in humidity, precipitation, and temperature). In this study these complex factors co-varied among the zones of insect origin and may explain the variation in *C. maculatus* body size. Furthermore *C. maculatus* populations from Niger and Burkina Faso are geographically closer compared to Senegal strain which can explain why a relative homogeneity was noticed between Niger and Burkina strains. Finally morphological and physiological plasticity in insects is often thought to represent an adaptive response to variable environments [26]. However such morphological adaptations are to be correlated with genetic features [27].

Our results also indicated that life history traits varied in accordance with body size variations. Therefore the Dakar strain had lower biotic potential (intrinsic rate of natural increase) compared to strains from Burkina Faso and Niger. These results are consistent with those of previous studies that showed that body size of an insect influences its life history traits [28]. It is generally assumed that larger size, particularly in females, provides a reproductive advantage [29-32]. The life history traits that are particularly influenced by the size of females include longevity, fecundity and egg size. Interestingly female lifespan and fecundity were significantly reduced in the Dakar strain composed of smaller individuals.

This study highlights some morphological and biological diversity of *C. maculatus* populations from three countries in West Africa. If such diversity can be seen as a result of adaptation of each population in its area of origin it remains to understand why the strain from Dakar in Senegal selects smaller individuals resulting in a lower biotic potential. In all cases this information is useful to establish the destructive capacity of each population in order to optimize pest control methods.

5. Acknowledgement

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