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Development and reproductive parameters of *Corcyra cephalonica* (Stainton) according to two agro-ecological zones of Senegal

Mamadou Lo, Toffène Diome, Cheikh Thiaw and Mbacké Sembène

Abstract
Originating in Africa, millet constitutes with sorghum the basis of food crops in Sahelian countries. Millet and sorghum represent a resistance challenge because, cultivated in population, they have strong capacities of adaption in extreme conditions. The study aims to determine the effect of agro-ecological zones on the biological parameters of *Corcyra cephalonica* (Stainton). Thus, millet samples were taken from a public store in the groundnut basin center and in the Senegal River delta on stocks. They were placed in rearing jars until adult emergence. The eggs collected from the latter had been used to carry out the necessary controls on biological parameters between agro-ecological zones. The results showed a non-significant agro-ecological zone effect on egg incubation time but which were higher in absolute values in *C. cephalonica* populations from the groundnut basin centre. The total number of eggs laid and the percentage of egg hatch were higher in populations from the Senegal River delta. However, this study also revealed a significantly different zone effect on the size, number of eggs laid and different development durations of the insect.

Keywords: *Corcyra cephalonica*, agro-ecological zones, millet, biological parameters

Introduction
Senegal's arable land is estimated at 3.8 million hectares, i.e. 19% of the country's total area. They are mainly located in the Groundnut Basin (57%), Casamance (20%) and Eastern Senegal (10%). The Senegal River Valley, the Sylvopastoral zone and the Niayes zone follow with 8%, 4% and 1% of arable land respectively. Of these arable lands, 2.8 million hectares are actually cultivated, representing 61% of the cultivable area and 12% of the country's surface area. For the 2012-2013 agricultural year, 1,248, 507 ha have been sown with cereals for a total production of 1,669,960 Tons. Millet leads with 40% of total cereal production, followed by rice 38%, maize 14% and sorghum 8% [1]. Thus, millet is the most cultivated cereal in Senegal, with 71% of the area sown with cereals for the 2011-2012 crop year and 65% in the 2012-2013 crop year. It weighs on average 42% of the total cereals produced in our territory although it only represents 26% of the quantity of cereals present in the Senegalese diet [1]. However, farmers pay little attention to millet, rice and maize stocks [2] which are attacked by insect pests such as *Corcyra cephalonica* (Stainton) which is a pest exclusively dependent on cereal stocks. It infests rice, millet, wheat, maize and legumes [3]. Andrewartha et Birch [4] have stated that the longevity and reproductive potential of insects are influenced by environmental components, including temperature, humidity and food. In addition, several studies have shown that the type of food substrate has a base on the developmental parameters of the moth, as demonstrated by LO *et al.* [5]. Does the agro-ecological zone also have a base on the biological parameters of the pest ? Knowledge of the impact of different agro-ecological zones on the insect is essential for its bio-control and better integrated management of ringworm. What would be the effect of agro-ecological zones (groundnut basin centre and Senegal River delta) on the development parameters of *C. cephalonica* and its reproductive potential ? The two agro-ecological zones (groundnut basin centre and Senegal River delta) have different climatic conditions that would probably influence the biology of the moth. It is in this context that the present study aims to determine the effect of these two agro-ecological zones on the development and reproductive parameters of *Corcyra cephalonica* (Stainton), in order to compare the evolution of its biological parameters between zones and to improve the conservation of cereals.

Materials and methods
Sampling site
The choice of the sampled sites was made with reference to their importance in terms of storage capacity, their geographical position with agro-ecological areas and neighbouring countries. The millet samples were taken at the groundnut basin centre in a seed packing station located at 14° 39' 4.5" N; 16° 15' 19.36" W belonging to the Sahelo-Sudanian zone (SAS) and in the Senegal River delta, from local traders, at Ross Béthio in Dagana department with the following geographical coordinates: 16° 16’ 41,95’’ N ; 16° 8’ 38,55’’ W belonging to the Sahelian zone (see figure 1 and Table 1).

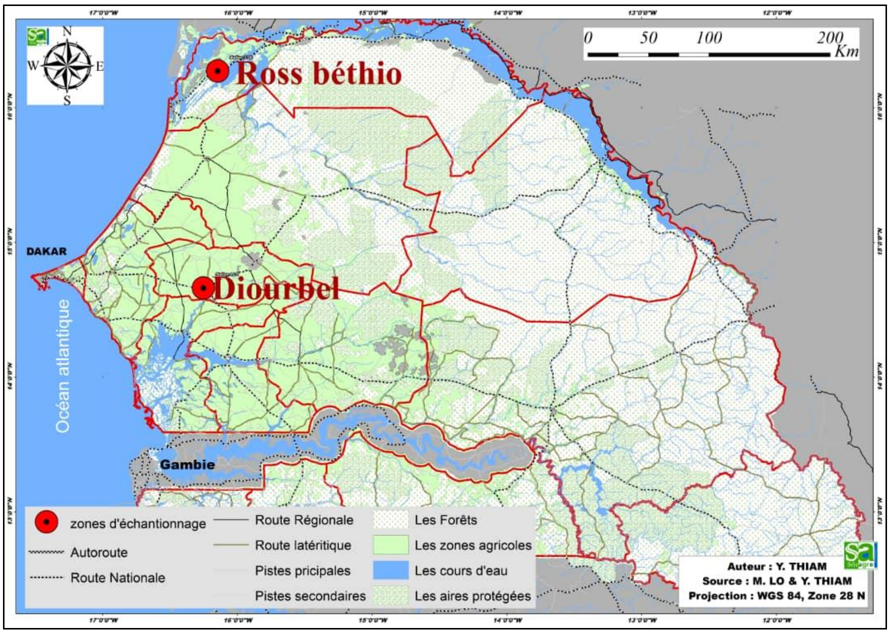

Fig 1: Geographical location of localities sampled in agro-ecological zones.

Table 1: List of millet samples infested with *C. cephalonica*, by geographic location and associated acronyms.

Z.A.E	Geographical coordinates	Code	Type of storage infrastructure
(CBA)	14° 39’ 4,50’’ N ; 16° 15’ 19,36’’ W	MDlCBA	State store
(DFS)	16° 16’ 41,95’’ N ; 16° 8’ 38,55’’ W	MRbDFS	Producer store

Caption : Z.A.E = Agro-Ecological Zone ; CBA = Groundnut Basin Centre ; DFS = Senegal River Delta ; MDlCBA = Millet Diourbel Groundnut Basin Centre ; MRbDFS = Millet Ross béthio Senegal River Delta

On arrival at the storage centers and during storage, the quality and state of preservation of the products were checked. Thus, for a given batch of grain, the number of bags from which samples were taken depended on the total number of bags stored. In fact, out of a batch of 100 bags, 10 were randomly selected to compose the overall sample, and the samples were taken on a random basis. Fifty (50) g per 100 kg bag of millet were collected, sufficient to form an overall sample of at least 500 g.

Moth breeding
To follow the various biological parameters of the moth, it’s necessary to set up mass rearing. It was carried out in the laboratory using strains of *C. cephalonica* from millet samples. The harvested cereals were placed in rearing jars placed in a controlled environment chamber until adult emergence. The adults had been in the jars for 24 hours to encourage mating and sexing. After sexing, the moths were individually placed in minuscule drums of fine-mesh wire mesh to collect the eggs laid by the females and to study the insect's bio-ecology. Egg hatching and butterfly emergence dates were noted. These eggs were used to study development parameters.

Study of the development of the rice borer
Twenty (20) boxes with wire mesh lids each containing 20g of cold sterilized millet, were used and divided into two dozen. The moth eggs, although visible to the naked eye, were collected, placed on a white sheet of paper and checked under magnifying glasses (binocular and hand held) to form batches of ten (10) eggs from MDlCBA on the one hand, and MRbDFS on the other. For sowing, using the head of a fluted probe, each ten (10) eggs were slipped and placed on a box placed under and at the edge of the sheet. The development of the insects took place in these boxes until the emergence of the adults.

Egg incubation
The egg incubation or embryonic life span is the time between the release of an egg and its hatching. The eggs laid by the female were incubated in Petri dishes placed in the controlled environment chamber. Monitoring was daily under a cold light magnifying glass to count the eggs hatched in relation to the total laid.

Pupal-laying, pupal and butterfly lifespan durations
The pupal-laying duration is the time between egg release and the beginning of pupation. The pupal duration is the time between the beginning of pupation and the emergence of the butterfly. With the date of sowing noted, daily observations to determine these three types of duration were made. The lifespan of the butterfly or longevity of the adults was assessed from the emergence of the butterfly until its death.

C. cephalonica life cycle
The life cycle of the moth corresponds to the time between the release of an egg and the death of the butterfly. It is therefore equal to the sum of the pupal-laying, pupal and butterfly lifespan.

Adult biometry of _C. cephalonica_
Adults from all 20 culture boxes were sexed. Biometric measurements were taken under a binocular magnifying glass equipped with a graph paper. They consisted of measuring the length and width of the codling moth.

Reproduction study
Ten drums, each containing a female of *C. cephalonica* copulated in the rearing boxes, were placed in an emergency chamber of the laboratory. The females laid a significant amount of eggs in the drums.

Number of spawns
It corresponds to the total number of eggs laid by a female. The laying of eggs begins 24 hours after copulation and is spread over a long period of the female's life, as the laying activities occupy 60% of the imaginary lifespan and the egg-laying speed decreases steadily during this period [6]. Charnov & Skinner [7] note that under natural conditions insects often mate with several partners and lay eggs several times.

Eggs laid per female
Eggs laid were poured through the wire mesh of the drum and recovered at the secondary drum plug. The eggs were counted daily after each laying until the end of the laying and the female death. Oviposition is an extremely important phase of an insect's life and must occur at the right time and in the right place in order to maximize the survival probabilities of offspring [8, 9]. Fecundity was calculated after 24 hours of laying.

Egg fertility
Hatched eggs counted to determine the incubation time themselves were used as an index to determine the fertility of the eggs laid per female. Egg fertility is the number of eggs hatched relative to the total number of eggs laid during a lay.

Statistical analysis
Rice borer development and reproductive parameters were processed using EXCEL® 2016 and XLSTAT 2014. lnk software. The Excel spreadsheet was used for data collection. XLSTAT has been used to do ANCOVA (Analysis of Covariance) which can be seen as a mix of ANOVA and linear regression since the dependent variable is the same, the model is also a linear model, and the assumptions are identical. For cases where these conditions were not verified, non-parametric Mann-Withney type tests were performed. Differences in means between the different populations taken in pairs were compared by the smallest significant difference at the 5% threshold.

Results
Effect of agro-ecological zones on the development parameters of _C. cephalonica_
Study of moth reproduction parameters
The number of female moths egg-laying in the groundnut basin center is twice that of moths from the Senegal River delta, 6.5±2.39 egg-laying and 3.25±1.49 egg-laying respectively, on millet grains. The mean difference between the number of eggs laid in agro-ecological areas is significant (p-value = 0.0142 < 0.05). The average total number of eggs laid per female is higher with moths from the Senegal River delta (121.13±71.69 eggs) than those from the groundnut basin center (86.75±47.13 eggs). The mean difference between these total numbers of eggs laid in agro-ecological zones is not significant (p-value. = 0.4306 > 0.05). The hatching percentage is higher for populations from the Senegal River delta (29.85±14.55%) than those from the groundnut basin center (28.33±7.53%), but their difference in average is not significant (p-value. = 1 > 0.05).

Effect of agro-ecological zones on egg incubation time
Incubation times are approximately equal (4.71±0.27 days and 4.71 ± 0.99 days) in both zones and the difference between the development times of the two populations is not significant (p-value = 0.2813 > 0.05).
The analysis in Table 2 shows that the means durations of the different stages of *C. cephalonica* development are higher for moths from CBA. So we can speak of a zone effect on these biological parameters. The calculated p-value (< 0.0001) is below the significance level alpha = 0.05. Laying-nymph, pupal, longevity and total moth cycle durations between agro-ecological zones are very significantly different.

Table 2: Duration of the different stages of development of the female of the rice moth according to the agro-ecological zones of the center of groundnut basin and the delta of the Senegal river on millet grains

Variable	ZAE	Obs.	Minimum	Maximum	Average	Standard deviation	P-value
duration of egg-laying	DFS	11	17	26	21.3636	3.4430	< 0.0001
	CBA	11	57	61	58.9091	1.0445	
pupal duration	DFS	11	10	13	11.2727	1.0090	< 0.0001
	CBA	11	14	30	22.1818	4.8542	
adult longevity	DFS	11	4	6	4.6364	0.8090	< 0.0001
	CBA	11	8	14	9.9091	2.0715	
Total cycle time	DFS	11	34	42	37.2727	3.5802	< 0.0001
	CBA	11	80	98	91.0000	5.0398	

Biometric study of the rice borer according to agro-ecological zones
The size of moths evolves differently depending on the agro-ecological zone. Females are larger than males. Moths from DFS are longer than CBA moths while CBA insects are wider than DFS moths (11±0.87 mm long and 2.36±0.32 mm wide for females, 9.27±0.75 mm long and 2.12±0.22 mm wide for males, for populations of the Senegal River delta ; 10.32±0.64 mm long and 2.82±0.72 mm wide for females and 8.42±0.64 mm long and 2.31±0.48 mm wide for males, for populations from the groundnut basin center).
Analysis of variance revealed that the mean insect lengths between agro-ecological zones are significantly different (p-value = 0.0136 < 0.05) (see Table 3).

Table 3: Analyse of variance (Variable length (mm))

Source	DDL	Sum of squares	Average of squares	F	Pr > F
Model	1	8.5939	8.5939	6.5465	**0.0136**
Fault	50	65.6369	1.3127		
Total corrected	51	74.2308			
Calculated against the model Y = Average (Y)					

The graph of means (Figure 2) confirms that the mean moth length is higher in the Senegal River delta area.

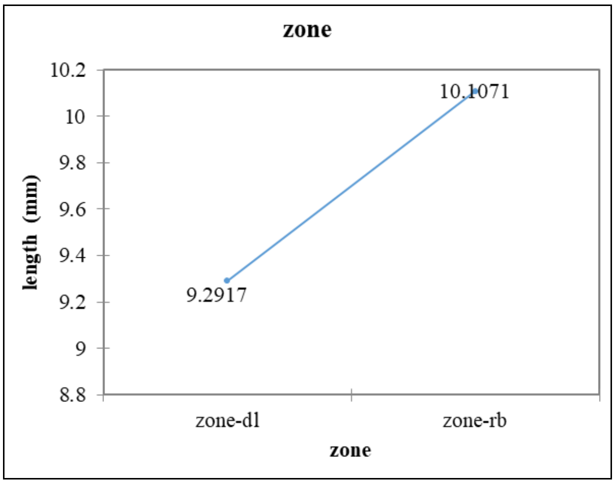

Fig 2: Average length of the rice moth as a function of agro-ecological zones

Zone / Tukey (HSD) / Analysis of differences between butterfly sizes with a 95% confidence interval :

The Tukey test gives a p-value = 0.0136 < 0.05 and two different groups for the means, confirming that the difference between the mean lengths of the dry grain ringworm in agro-ecological zones is significant.

The analysis of variance shows that the effect of the agro-ecological zone on moth width is significantly different (p-value = 0.0350 < 0.05) (see Table 4).

Table 4: Analysis of variance (Variable width (mm)

Source	DDL	Sum of squares	Average of squares	F	Pr > F
Model	1	1.0994	1.0994	4.6948	**0.0350**
Fault	50	11.7083	0.2342		
Total corrected	51	12.8077			
Calculated against the model Y = Average (Y)					

The graph of means confirms that the mean moth width is higher in the groundnut basin center zone (see figure 3).

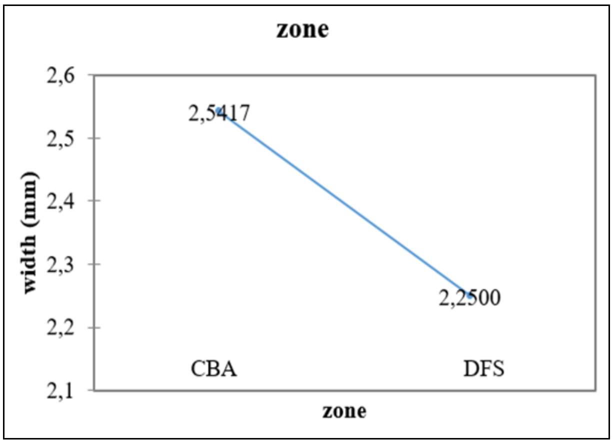

Fig 3: Average width as a function of agro-ecological zones

The average insect widths between agro-ecological zones are significantly different because they belong to two different groups and in addition the p-value = 0.0350 < 0.05 (see Table 5).

Table 5: Summary for all Y

	length (mm)	width (mm)
R^2	0.1158	0.0858
F	6.5465	4.6948
Pr > F	0.0136	0.0350
zone	6.5465	4.6948
	0.0136	0.0350

The size evolves differently according to the origin zone of the rice borer: the insects in the Senegal River delta zone are longer but less wide while those in the groundnut basin center are shorter but wider (see Figure 4). Thus the agro-ecological zone has a significantly different effect on the size of *C. cephalonica* (see Table 5).

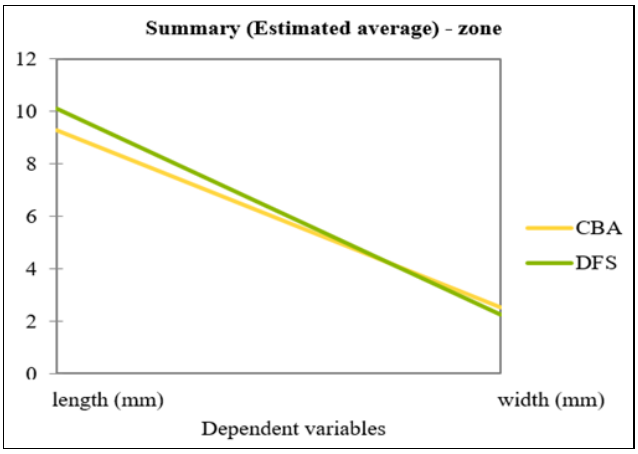

Fig 4: Average size according to the Diourbel and Ross Béthio localities

Discussion

The study shows that the number of egg-laying is higher in the groundnut basin area (6.50 ± 2.39 eggs laid) than in the Senegal River delta area (3.25 ± 1.49 eggs laid) with a significant mean difference (p-value = 0.0142 < 0.05). Jagadish and *et al.* [10] reported a spawning period of 6 to 8 days on millet. Their result confirms that of the groundnut basin zone populations but contradicts that obtained with those of the Senegal River delta. The average total number of eggs laid per female is higher with moths from Ross Béthio (123.13±71.69 eggs) than with those from the groundnut basin zone (86.75±47.13 eggs). The difference in the total number of eggs laid by female moths from millet grains between agro-ecological zones is not significantly different (p-value = 0.4306 > 0.05). Kumar and *et al.* [11] reported 298 eggs on sorghum. This is much higher than the number of eggs obtained in this study. These differences could be explained by environmental conditions (temperature and air humidity among others), the nature and quality of the grain or the insect strain itself. On the other hand, the hatching percentage is higher with populations from the Senegal River delta than with those from the groundnut basin center zone with a non-significant difference (p-value = 1 > 0.05). Depending on the geographical origin of the host cereals, the results show that, on millet grains, the incubation times of eggs from populations of the two agro-ecological zones are roughly equal (4.71±0.27 days for DFS populations and 4.71 ± 0.99 days for CBA populations) and their difference is not significant (p-value. = 0.2813 > 0.05). Bhubaneshwaridevi and *et al.* [12] results are in agreement with our study as they report that the embryonic development duration is 4 to 7 days. Furthermore, the egg-laying, pupal and total cycle durations are higher in moths from the groundnut basin center zone than those from the Senegal River delta populations with a significant difference (p-value = < 0.0001). We can thus say that the effect of the agro-ecological zone has a significant underpinning on the development parameters of the codling moth. This difference would be induced by the climatic conditions prevailing in the two localities, which are sources of local adaptation of the rice borer. Ayyar [13] had determined a larva-nymph period of 57 days on sorghum, which is close to the result on the larva-nymph duration obtained (54 days) at the CBA, knowing that the embryonic duration is about 5 days. According to Jagadish and *et al*. [10], the larval-nymph period varies between 28 and 36 days with an average of 31.26 days on millet; which is longer than the larva-nymph duration (16 days) found in populations from the Senegal River delta. Jagadish and *et al*. [10], found a pupal period that varies between 9 and 16 days with an average of 13.06±0.86 days for the millet moths; which is shorter for populations from the groundnut basin center and slightly longer for those from the Senegal River delta. According to Bhubaneshwaridevi and *et al.* [12], the pupal period varied from 9 to 19 days. This is close to our results obtained for the two agro-ecological zones (CBA and DFS). According to Bhubaneshwaridevi and *et al.* [12], adults were more active at nightfall. The longevity of male and female butterflies varied from 9-12 and 12-15 days respectively, which confirms the results of this present study for insect populations from the groundnut basin center and contradicts the conclusions of our study for those from the Senegal River delta. Kumar and *et al*. (2007) [14] also reported that adult longevity ranged from 1.5 ± 0.5 to 11.9 ± 1.3 days for males and 1.5 ± 0.5 to 16.5 ± 1.2 days for females, which corroborates our conclusions. Ashwani and *et al.* [11] documented a total insect lifespan of 45.82 days in sorghum, which is shorter for moths in the groundnut basin center area but slightly higher for populations in the Senegal River delta. Chaudhuri and Senapati [15] reported that the average generation time ranged from 46.08 to 48.76 days in millet, which was confirmed by Jagdish and *et al*. [10] and Pathak and *et al*. [16] and is close to the result obtained for moths from the Senegal River delta zone. On the other hand, the size of female moths is larger than that of male moths. The length of moths from the Senegal River delta zone is greater than that of moths from the groundnut basin center zone ; however, the width of the insects evolves differently. The difference in insect size between the two agro-ecological zones is significant. Thus, the size evolves differently according to the origin zone of the rice borer: the insects in the Senegal River delta zone are longer but less wide while those in the groundnut basin center zone are shorter but wider with significant differences in average. We can say that there is an area effect on the size of *C. cephalonica* that could be inscribed on the genome of this insect. Bhubaneshwaridevi and *et al.* [12] reported that the length of the male butterfly was 10.75 mm and the width was 5.27 mm. The length and width of the female butterfly was 12.24 and 5.21 mm respectively. The minimum and maximum temperature and humidity mean were 12.1 °C, 27.9 °C and 71.7%, respectively. These are all similar parameters also reported by Hemchandra and Singh [17]. Their results corroborate ours for moth length and sexual dimorphism and contradict the conclusions of this study with respect to the width of the moth.

Conclusion

The study revealed a significant zone effect on the durations of the different phases of development of the insect as well as on fecundity, which is in favor of the populations of *C. cephalonica* coming from the center of the groundnut basin. However, this effect is not significant on the total number of eggs laid and the percentage of eggs hatching which are higher in populations from the Senegal River delta. This study also revealed a significantly different area effect on the size of the insect. This study therefore provided new information on the bio-ecology of *C. cephalonica*, its behavior towards agro-ecological zones in the center of the groundnut basin and the Senegal River delta. These data will no doubt allow better management of populations of this insect pest of stored food, including the agro-ecological conditions of ecosystems.

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