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Research Article

Intraspecific Competition of *Carpophilus hemipterus* (Coleoptera: Nitidulidae) on Two Yam Cultivars under Laboratory Conditions in Burkina Faso

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Abstract

Background and Objective: *Carpophilus hemipterus* is an important storage pest of yam tubers, and its reproductive performance may be influenced by resource quality and intraspecific competition. The present study aimed to investigate the effect of intraspecific competition on the reproductive performance, development, and morphological traits of *C. hemipterus* when reared on two yam cultivars under laboratory conditions in Burkina Faso. **Materials and Methods:** In the first experiment, pair of newly emerged adult *C. hemipterus* were formed and placed in plastic boxes in groups of 1, 2, 3, 4 or 8 pairs, each group was placed in contact with 10 g of chips from each cultivar (x5 replicates). In the second experiment, From the emergence of each density previously tested, five pairs were formed and individually placed in contact with 10 g of chips in plastic boxes. The parameters determined were mean number of eggs laid per female, mean number of emergents produced per female and mean height and weight of emerged individuals. Statistical analyses were performed in R (v4.2.1) using the Shapiro–Wilk test for normality and Student's t-test for normally distributed data ($p<0.05$). **Results:** The average water content of Sakampé chips (29.45%) was significantly higher than that of Ponon (22.65%), irrespective of competition effects. Increased intraspecific competition significantly reduced ($p<0.05$) fertility, as well as the weight and size of the first-generation adults. However, no significant differences ($p>0.05$) were observed in the weight and size of emerging individuals between the different competition treatments in the presence of the two yam cultivars. **Conclusion:** Intraspecific competition negatively affects the reproductive performance of *C. hemipterus*. These findings provide a useful basis for developing effective pest management strategies for yam storage systems.

Key words: *Carpophilus hemipterus*, intraspecific competition, chips, yams, Burkina Faso

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Organisms in natural ecosystems do not live in isolation but are involved in complex networks of interactions with other species and their environment[1,2]. The entities involved in the interaction can be individuals of the same or different species[3]. Moreover, these organisms are directly influenced by the amount of sunlight, access to water, and nature of the soil, which together constitute abiotic factors[4] (among these abiotic factors, variations in temperature and humidity disrupt the development of living organisms, particularly insects[5,6]. Insects inhabit all habitats owing to their small size, relatively short generation time, well-developed sensory organs, and bodies covered with an impermeable cuticle. Variation in environmental parameters (temperature and humidity) affects insect morphology, survival, egg production, and behavior[7-9]. Individuals of the same species generally require the same resources for growth, reproduction, and survival. These resources are usually food, sexual partners, shelters, nesting sites, and egg-laying sites.

At the population level, certain insect behaviors can impact biological performance. This is particularly the case with intraspecific competition, which occurs when individuals of the same species must share the same resources, especially if these are limited as the population increases[10] (indeed, competition for food would result in a reduction in the number of individuals in the next generation[11] (some authors have shown that competition affects the reproductive capacity, biological vigor of females, and emergence of individuals from the next generation[12,13] (intraspecific competition in *Callosobruchus maculatus* Fab. leads to an increase in the mortality rate and a reduction in the emergence rate)[14]. Intraspecific competition in *Spermaphagus niger* is influenced by temperature and substrate, leading to a reduction in egg laying and emergence rate at a certain population density[15].

However, no data have yet addressed the specific case of the behavior of *C. hemipterus* on the cossettes of yam cultivars. Knowledge of pest behavior is a sine qua non for developing effective control methods. Therefore, the present study aimed to determine the effect of competition on the reproductive parameters of *C. hemipterus* in the presence of slices from two yam cultivars and the reproductive potential of individuals from different competitive situations in the presence of slices from two yam cultivars.

MATERIALS AND METHODS

Study area and duration: The present study was carried out at the Laboratory of Fundamental and Applied Entomology (LEFA), Joseph KI-ZERBO University, where the temperature averaged 24.58±2.62°C and the average relative humidity 68±0.08%. The experience took place from July 2024 to October 2025.

Plant and animal material: The plant material consisted of two yam slices obtained from the cultivars Ponon and Sakampé. These samples were obtained following sampling at the market and from producer stocks in Léo, in the Province of Sissili (Central-Western Region of Burkina Faso). cultivars. The slices were produced from 10 g slices of chips in each case. Similarly, the animal material composed of adults of *C. hemipterus* belonged to the same strain previously described.

Determination of the moisture content of the different yam cultivars: For each cultivar (Sakampé or Ponon), the tubers were cut into 10 g slices. The water content of the resulting chips was measured using a 210G-1MG desiccator. These chips were inserted into circular boxes (diameter = 8 cm, height = 5 cm) for the experiments. The displayed water content was recorded. This procedure was repeated five times for each experiment.

Effect of competition on *C. hemipterus* reproductive parameters in the presence of chips

From two yam cultivars: Pairs of newly emerged adult *C. hemipterus* were formed and placed in plastic boxes (diameter = 8 cm; height = 5 cm) in groups of 1, 2, 4, or 8 pairs, representing different levels of competition. Each group was placed in contact with 10 g of chips from each cultivar in five replicates. Every 4 days, the insects were removed from the plastic boxes and replaced in new boxes containing the chips until the death of the females. After the removal of insects, the eggs laid were counted. The boxes containing the incubated eggs and chips were placed on the laboratory bench for monitoring. Two weeks after laying, the sterilized soil with boiling water was placed in each box to allow for pupation and emergence of adults. Emerging insects were counted according to sex. The weight and size of 30 insects, including 15 males and 15 females from each group of pairs, were measured using an OHAUS ultrasensitive balance (0.0001-110 g) and a Leica binocular Loupe equipped with a graduated ruler.

The data collected made it possible to determine the following parameters:

- Mean number of eggs laid per female
- Mean number of emergents produced per female
- Mean height and weight of emerged individuals

Reproductive potential of *Carpophilus hemipterus* individuals from different competitive situations in the presence of substrates from two yam cultivars: From the emergence of each density previously tested, five pairs were formed and individually placed in contact with 10 g of chips in plastic boxes (radius = 4 cm, height = 5 cm) until the death of the female. The number of eggs laid was then counted under a binocular loupe, and the eggs were incubated. Two weeks later, sterilized soil with boiling water was placed until the emergence of adults, as in the previous experiment. The average weight and size of 30 insects, including 15 males and 15 females, were measured. The same parameters as mentioned above have been determined.

Statistical analysis: Data normality was assessed using the Shapiro-Wilk test. A two-way ANOVA was performed to evaluate the effects of yam cultivar and competition level. Means were separated using Tukey's HSD test at $p<0.05$. All analyses were conducted using R version 4.2.1.

RESULTS

Determination of the rate of water content of the chips of the different cultivars: Table 1 shows that the mean water content rate of the Sakampé chips (29.45) is significantly higher than that of Ponon (22.65), regardless of the competition effect (direct or indirect). However, for the same chips, the mean rate of water content does not affect *C. hemipterus*, whether the competition is a direct or indirect effect.

Effect of competition on the reproduction parameters of *Carpophilus hemipterus*

Mean number of eggs deposited per female: *Carpophilus hemipterus*. Moreover, on the two substrates, this mean number was significantly affected only in the competitive situation where there were 8 pairs (Table 2).

Mean number of emerged insects per female *Carpophilus hemipterus*: The mean number of individuals produced per female was significantly reduced in the different competitive situations from two to eight pairs regardless of the chips (Table 3). In contrast, by comparing this parameter according to the chips, the Sakampé chip was significantly higher for the situations of one and two pairs of *C. hemipterus*. However, no significant difference was observed for the situations of four and eight pairs (Table 3).

Morphometric parameters of *C. hemipterus*: The mean weight of first-generation individuals was significantly affected by competition and cultivars (Table 4). Indeed, the individuals that developed on Sakampé had a higher weight, regardless of the competition situation. However,

Table 1: Mean rate water content (%) of cultivated substrates used in *C. hemipterus* breeding

Parameter	Water rate content (%)		p-value
Chips	Direct effect	Indirect effect	
Sakampé	29.45 ± 0.30^{Aa}	28.85 ± 0.32^{Aa}	0.78
Ponon	22.65 ± 0.42^{Ba}	22.25 ± 0.40^{Ba}	0.84
F	185.2	5.805	
p-value	0.00005	0.0003	

Means±Standard deviations with the same alphabetic letters in lower case on the same line and those with the same capital letters in the same column are not significantly different according to the Newman and Keuls test at a probability threshold of 5%

Table 2: Influence of different competition situations on the average number (±SD) of eggs per female *C. hemipterus* on the two yam cultivars

Level of competition	Cultivars/chips Ponon	Sakampé	F	p-value
1 pairs	54.8 ± 3.8^{Aa}	65.2 ± 5.5^{Ab}	7.99	0.008
2 pairs	47.0 ± 3.8^{Aa}	56.0 ± 4.4^{Ab}	5.11	0.001
4 pairs	42.8 ± 2.9^{Aa}	49.8 ± 2.5^{Ab}	4.32	0.003
8 pairs	32.6 ± 2.4^{Ba}	39.0 ± 3.0^{Bb}	2.13	0.03
F	14.3	18.56		
p-value	0.0008	0.0001		

Averages (±Standard deviations) with the same lower-case letters are not significantly different) at the 5% probability threshold on the same line (Student's t-test), and those with the same capital letters in the same column are not significantly different at the 5% probability threshold (ANOVA by permutation followed by the Chi-square test) and SD: Standard deviation

Table 3: Influence of different competitive situations on the average productivity (±SD) per female *C. hemipterus* on two yam cultivars

	Mean number of emerged insects per female			
Level of competition	Ponon	Sakampé	F	p-value
1 pairs	37.2±0.9^{Aa}	49.0±3.0^{Ab}	1.37	0.04
2 pairs	27.4±0.5^{Ba}	35.8±1.9^{Bb}	2.76	0.02
4 pairs	22.4±1.0^{Ca}	22.2±1.7^{Ca}	1.49	0.32
8 pairs	15.0±1.0^{Da}	17.0±0.7^{Da}	0.41	0.50
F	8.40	18.5		
P value	0.00001	0.0001		

Averages (±Standard deviations) with the same lower-case letters are not significantly different) at the 5% probability threshold on the same line (Student's t-test), and those with the same capital letters in the same column are not significantly different at the 5% probability threshold (ANOVA by permutation followed by the Chi-square test) and SD: Standard deviation

Table 4: Influence of different competitive situations on the average weight (±SD) of first-generation *C. hemipterus* individuals on two yam cultivars

	Mean weight (mg) of individuals			
Level of competition	Ponon	Sakampé	F	p-value
1 pairs	0.91±0.036^{Aa}	1.40±0.09^{Ab}	1.33	0.04
2 pairs	0.91±0.030^{Aa}	1.39±0.08^{Ab}	7.97	0.008
4 pairs	0.90±0.031^{Aa}	1.39±0.06^{Ab}	6.81	0.006
8 pairs	0.80±0.028^{Ba}	1.07±0.05^{Bb}	2.10	0.03
F	3.04	4.97		
p-value	0.03	0.003		

Averages (±Standard deviations) with the same lower-case letters are not significantly different) at the 5% probability threshold on the same line (Student's t-test), and those with the same capital letters in the same column are not significantly different at the 5% probability threshold (ANOVA by permutation followed by the Chi-square test), SD: standard deviation and SD: Standard deviation

Table 5: Influence of different competitive situations on the average size (±SD) of first-generation *C. hemipterus* individuals on two yam cultivars

	Mean size (mm) of individuals			
Level of competition	Ponon	Sakampé	F	p-value
1 pairs	2.6±0.0^{Aa}	2.7±0.0^{Ab}	2.16	0.03
2 pairs	2.6±0.0^{Aa}	2.7±0.0^{Ab}	5.13	0.001
4 pairs	2.6±0.0^{Aa}	2.7±0.1^{Ab}	2.12	0.03
8 pairs	2.4±0.1^{Ba}	2.5±0.0^{Bb}	1.35	0.04
F	5.27	18.39		
p-value	0.002	0.0001		

Averages (±Standard deviations) with the same lower-case letters are not significantly different) at the 5% probability threshold on the same line (Student Test) and those with the same capital letters in the same column are not significantly different at the 5% probability threshold (ANOVA by permutation followed by the Chi-square test) and SD: Standard deviation

Table 6: Mean number of eggs laid (±SD) depending on the level of competition

	Cultivars/Chips			
Level of competition	Ponon	Sakampé	F	p-value
1 pairs	55.6±4.15^{Aa}	63.2±5.44^{Aa}	1.47	0.35
2 pairs	49.8±3.96^{Aa}	58.4±6.06^{Aa}	1.90	0.34
4 pairs	49.4±3.54^{Aa}	57.6±6.10^{Aa}	1.42	0.30
8 pairs	48.8±4.08^{Aa}	56.8±4.77^{Aa}	1.91	0.33
F	2.58	1.58		
p-value	0.11	0.26		

Averages (±Standard deviations) with the same lower-case letters are not significantly different) at the 5% probability threshold on the same line (Student's t-test) and those with the same capital letters in the same column are not significantly different at the 5% probability threshold (ANOVA by permutation followed by the Chi-square test) and SD: Standard deviation

competition had a significant effect on mean progeny weight only in the presence of eight pairs on both cultivars (Table 4). The same observations were made with respect to the mean size of the first generation (Table 5).

Reproductive potential of individuals from different competitive situations in the presence of two yam cultivars

Mean number of eggs laid per female: Table 6 shows that regardless of the number of pairs and the type of chips, the mean number of eggs laid was not significantly different.

Table 7: Average number of individuals produced per female (±SD) depending on the level of competition

	Average productivity			
Level of competition	Ponon	Sakampé	F	p-value
1 pairs	33.69 ± 2.17^{Aa}	37.35 ± 2.00^{Aa}	1.82	0.45
2 pairs	33.49 ± 1.66^{Aa}	37.44 ± 2.87^{Aa}	1.39	0.29
4 pairs	31.93 ± 1.82^{Aa}	35.28 ± 1.57^{Aa}	1.65	0.45
8 pairs	31.61 ± 1.13^{Aa}	35.23 ± 2.55^{Aa}	1.46	0.35
F	0.67	0.76		
p-value	0.61	0.55		

Averages (±Standard deviations) with the same lower-case letters are not significantly different) at the 5% probability threshold on the same line (Student Test) and those with the same capital letters in the same column are not significantly different at the 5% probability threshold (ANOVA by permutation followed by the Chi-square test) and SD: Standard deviation

Table 8: Weight of individuals from the first generation of females according to competition level

	Mean weight (mg) of individuals			
Level of competition	Ponon	Sakampé	F	p-value
1 pairs	0.71 ± 0.03^{Aa}	1.2 ± 0.09^{Ab}	4.35	0.003
2 pairs	0.73 ± 0.04^{Aa}	1.22 ± 0.09^{Ab}	5.12	0.001
4 pairs	0.72 ± 0.04^{Aa}	1.21 ± 0.09^{Ab}	5.18	0.001
8 pairs	0.71 ± 0.03^{Aa}	1.21 ± 0.05^{Ab}	4.14	0.002
F	0.86	0.54		
p-value	0.96	0.99		

Averages (±Standard deviations) with the same lower-case letters are not significantly different) at the 5% probability threshold on the same line (Student Test) and those with the same capital letters in the same column are not significantly different at the 5% probability threshold (ANOVA by permutation followed by the Chi-square test) and SD: Standard deviation

Table 9: Size of individuals in the first generation of females according to competition level

	Mean size (mm) of individuals			
Level of competition	Ponon	Sakampé	F	p-value
1 pairs	2.44 ± 0.02^{Aa}	2.54 ± 0.01^{Ab}	2.52	0.01
2 pairs	2.46 ± 0.02^{Aa}	2.55 ± 0.04^{Ab}	2.15	0.03
4 pairs	2.46 ± 0.02^{Aa}	2.54 ± 0.01^{Ab}	2.11	0.03
8 pairs	2.45 ± 0.02^{Aa}	2.55 ± 0.03^{Ab}	2.51	0.01
F	0.82	0.47		
p-value	0.96	0.98		

Averages (±Standard deviations) with the same lower-case letters are not significantly different) at the 5% probability threshold on the same line (Student Test) and those with the same capital letters in the same column are not significantly different at the 5% probability threshold (ANOVA by permutation followed by the Chi-square test) and SD: Standard deviation

Mean number productivity per female *C. hemipterus*: Table 7 shows that regardless of the number mean of pairs and chip type, the average number of individuals produced per female was no significant difference.

Morphometric parameters of *C. hemipterus*: The average weight of individuals in different competitive situations was significantly affected by the cultivar (Table 8). Indeed, the individuals that developed on Sakampé had a higher weight, regardless of the competition situation. However, competition had no significant effect on the average weight of offspring, regardless of the number of pairs (Table 8). The same observations were made with respect to the mean emerging size (Table 9).

DISCUSSION

This study is the first to focus on the behavior of *C. hemipterus* on two yam cultivars produced in Burkina Faso. The results complement those obtained from biology and should contribute to a better understanding of the population structure of this insect in the yam storage systems. This understanding can help in better pest control.

The analysis of the results of the effect of intraspecific competition on the reproductive capacities of *C. hemipterus* highlights that an increase in the number of individuals can affect the average number of eggs per female, particularly in the presence of eight pairs. This reduction can be explained by the fact that when there are several females, each one would spend more time searching for favorable areas of the substrate to ensure the survival of its offspring. Such research could lead to a greater expenditure of energy, hence the death of the female before the laying of all her eggs[16,17]. This could also be explained by the existence, as is the case with certain stored-food beetles, of a lipid-derived substance called 'Biological Conditioning Substance' or BCS emitted at the same time as the first eggs, which would have a repulsive effect on females for new laying[18,19]. The decrease in the average number of offspring per female in competitive situations could be correlated with high mortality during development following larval overcrowding. This would then lead to a reduction in resources for the larvae and greater mortality[20,21], accompanied by a decrease in the weight and size of the descendants from extreme competitive situations[17].

The reproductive potential of individuals from competition did not affect fertility or the average number of individuals produced per female, regardless of their origin and substrate type. These results could be explained by the fact that competition acts as a selective filter, meaning that the individuals who survive are mostly the most robust (best physiological and anatomical condition), which would allow them to maintain their fertility and emerging insects[11]. Regarding morphometric parameters, the progeny of *C. hemipterus* showed greater size and weight on Sakampé than on Ponon, regardless of their origin. This confirms that the substrate derived from the cultivar Sakampé had more favorable factors for insect growth.

While providing useful information on the biology and behavior of *C. hemipterus*, it is generally clear that the two tested cultivars are susceptible to the pest, thus limiting the potential exploitation of varietal resistance. To better control the pest within the perspective of integrated management, it is necessary to explore other methods.

CONCLUSION

This study shows that an increase in the number of pairs of *C. hemipterus* exploiting a limited substrate led to a reduction in insect life traits (fecundity per female, productivity per female, and morphometric parameters), particularly in the competitive situation provided by eight pairs. In this situation, a significant decrease in individual reproductive capacity as well as height and weight, was observed. However, the different competitive situations is no effect on fertility and the average number of individuals produced per female that were derived from them. All of these studies will contribute to developing an effective control method against *C. hemipterus*.

SIGNIFICANCE STATEMENT

This study demonstrates that increasing intraspecific competition significantly reduces the reproductive performance and morphometric characteristics of *Carpophilus hemipterus* on stored yam cultivars. The findings provide new insights into the population dynamics of this important storage pest and offer valuable information for improving integrated pest management strategies for yam storage systems in Burkina Faso and similar agroecological regions.

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