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Influence of dietary factors of five varieties of beans sold in Côte d'Ivoire on some biological parameters of *Callosobruchus maculatus* (Fab.) Coleoptera, Bruchidae

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Mots clés : *Callosobruchus maculatus;* paramètres biologiques ; résistance ; *Vigna unguiculata*; *Phaseolus vulgaris* ; valeur nutritive.

1 SUMMARY

Callosobruchus maculatus is a major pest of beans storage. Several methods like biological control and chemical control, have been used to control this insect but have failed. Six biological parameters of _C. maculatus_ were studied on the seeds of five varieties of beans: two varieties of _Phaseolus vulgaris_ and three of _Vigna unguiculata_ Walp., according to their physical and chemical characters. The results revealed that white cowpea IT97K499-38 has more energy with the highest level of protein, fat, and sugar with a thin tegument. On the two varieties of _Phaseolus_ , eggs laid did not develop. . Of the three varieties of Vigna , a comparison of average duration of the cycle of development, fecundity , and sex ratios of _C. maculatus_ showed no significant difference (P> 0.05) , unlike the emergence rate , weights and lifespan of adults. Variety IT97K499 -38 recorded the highest 80.86 % against 74 % emergence rate (F = 106.85, P < 0.0001) and the highest average weight (3.48 mg) against 2.87 and 2.83 mg on IT96D610 varieties and TVX1248. Variety IT97K499 -38 proved to be the most favourable for the development of _C. maculatus_ therefore the most sensitive. Resistance varieties of _Phaseolus vulgaris_, in combination with other control methods help to reduce infestations of seeds by insects during storage.

RÉSUMÉ :

Influence des facteurs alimentaires de cinq variétés de haricots vendus en Côte d'Ivoire sur quelques paramètres biologiques de _Callosobruchus maculatus_ (Fab.), Coléoptère, Bruchidae

Callosobruchus maculatus est un grand déprédateur des stocks de haricot. Plusieurs méthodes de lutte telles que la lutte biologique et la lutte chimique sont utilisées contre cet insecte mais restent insuffisantes. Six paramètres biologiques de ce ravageur ont été étudiés sur les graines de 5 variétés de haricots : 2 variétés de _Phaseolus vulgaris_ et trois de _Vigna unguiculata_ Walp., communément appelé niébé, en fonction de leurs caractères physico-chimiques. Les résultats ont révélé que le niébé blanc IT97K499-38 est la plus énergétique avec le plus fort taux de protéine, de matière grasse et de sucre avec un tégument fin. Sur les

variétés de *Phaseolus*, les œufs pondus ne se sont pas développés. Sur les trois variétés de *Vigna*, la comparaison des durées moyennes du cycle de développement, des fécondités, et des sex ratios de *C. maculatus* n'a révélé aucune différence significative (P>0,05), contrairement aux taux d'émergence, aux poids et aux longévités des adultes. La variété IT97K499-38 a enregistré le taux d'émergence le plus élevé de 80,86% contre 74,% (F= 106,85; P<0,0001) et le poids moyen le plus élevé (3,48 mg) contre 2,87 et 2,83 mg sur les variétés IT96D610 et TVX1248. La variété IT97K499-38 s'est avéré la plus favorable au développement de *C. maculatus* donc la plus sensible. La résistance des variétés de *Phaseolus vulgaris*, combinée à d'autres moyens de lutte contribuerait à réduire les infestations des graines par les insectes, durant le stockage.

2 INTRODUCTION

The seeds of leguminous plants like the seeds of the cowpea (*Vigna unguiculata* Walp) are widely consumed in Africa. They provide from 20% to 25% of proteins as well as available minerals. They are significant sources of income for small scale farmers, traders, agribusiness men and exporters (Ouédraogo, 2003; Nouhoheflin and *al*., 2003; Dabiré *et al*., 2003). Moreover, the genetic diversity of the bean is the basis for maintaining the means of subsistence and the agro-ecosystem. Therefore, it has a significant economic and socio-political importance. The world production of cowpea is put at 3.3 million tons of dry seeds, 64% of which are produced in Africa (FAO, 2001; 2011). However, people consume it by seasons, because the production and the storage are exposed to the depredation caused by many kinds of insects. Among those devastators, the Bruchidae is the most significant (Luca, 1975; Fleurat-Lessard, 1982). *C. maculatus* is a beetle. It measures on average 0.6± 0.1 cm. It lays its eggs on the surface of grain. After hatching, the larva develops itself inside the grain, and eats away the content of the seed, thus provoking post harvest loss ranging from 30% and 100% in few months(Alzouma, 1987; Lienard et Seck, 1994; Dabiré et al., 2003) if conservation techniques are not efficient.This consumption activity of seeds reserve by larvae provokes heat and moisture that cause the development of fungi such as *Aspergillus, Fusarium, Botrytis*, leading to quantitative losses. Once an adult, the insect emerges from the seed to lay their eggs other healthy seeds. *C. maculatus* thus leads weight reduction, but also decrease the quality and seed viability, compromising their consumption and seedlings (Singh and Singh, 1992; Odah, 1995). According to Murdock *et al.* (1997), when the damage exceedsone emergence hole by seed, the market value of cowpea is thereby substantially reduced. *Callosobruchus maculatus* (FAB.) that leads to the decrease in commercial quality of the seeds and their viability (Singh and Singh, 1992). Several techniques like biological control, chemical control, have been used to control those insects but have failed. The current study, in the framework of the global approach for a better storage of commodities, aims at studying in a laboratory, the influence of the food parameters of 5 varieties of beans on the biology of *C. maculatus*. The study parameters are the duration of the development cycle, the weight, the emergence rate and the sex ratio. This study would permit to select the beans that are less sensitive to their particular devastators in order to attain food security.

3. MATERIEL AND METHODS

3.1. Materiel: The biological materiel consists of five varieties of legumes with three varieties of cowpea identified according to the catalogue of varieties (CNEV, 2012; Balla and Baragé, 2006). They are the following:

- The white cowpea (wc), *Vigna unguiculata* Walp, Variety IT97K499-38,
- The red cowpea (rc), *Vigna unguiculata* Walp, Variety IT96D610,
- The purplish cowpea (pc), *Vigna unguiculata* Walp, Variety TVX1248.

Three local varieties of the cowpea have been taken from the market of Adjamé (Abidjan). There are two varieties of *Phaseolus* (Phr and Phb) which have been imported from France. - *Phaseolus vulgaris* Red Variety (Phr)

- *Phaseolus vulgaris white* (Phb

The pests consists of the *Callosobruchus maculatus* (FAB.) adults (Figure 1) aged 48 hours, taken for mass breeding carried out on the white cowpea, variety IT97K499-38 (originally food). The breeding material consists of two jars of 7 litres each covered with a muslin linen cloth used for the ventilation of extensive stock farming. Forty five cylindrical Petri box with 5 cm as diameter and a height of 1.1 cm were used for individual breeding. Binocular microscope used for the observations.

Figure 1 : Adulte femelle de *Callosobruchus maculatus*

3.2. Methods

3.2.1. Collecting and storing the seeds of the beans : The different varieties of beans are bought and kept in freezer for a week. Then the seeds are dried up at an ambient temperature of 24.4°C ± 0.8 in a laboratory for 2 days. The goal of these activities is to clear the seeds from potential chemical processing and to eliminate the larva in the seeds in order to have non infected seeds for the tests. The average height of a grain is determined by measuring one hundred seeds with a calliper. Each test is repeated three times. The morphologic characters and the chemical component of the seeds have been defined at the Central Laboratory of Animal Nutrition at ENSA, in Abidjan.

3.2.2. Collecting and Breeding *Callosobruchus maculatus* *:* At the market, the seeds of IT97K499-38, (the most infested variety) were sieved. The harvested adults of *Callosobruchus maculatus* were put in a jar containing 100 g of sound seeds of white cowpea *Vigna unguiculata* Walp, variety IT97K499-38 and transferred to the laboratory. Forty hours later, the insects were taken out, and the infected seeds are incubated till the emergence of the adults insects collected through sieving. Twenty four hours later, the sieved content of the container is once again sieved in order to obtain newly emerged adults. These adults will be used for the experimentations. A mass breeding and an individual breeding of the *C. maculatus* (FAB) are carried out in an average ambient temperature of 24.4°C ± 0.8 with a relative humidity of 76.20% ± 1.83. The mass breeding consists in putting «in bulk » the weevil in a 7-liter jars containing two kilogram of white cowpea (variety IT97K499-38). This breeding helps to obtain, constantly, a great number of weevils for the experimentations. The individual breeding is carried out in four cylindrical Petri box with 5 cm as diameter and with a height of 1.1 cm containing 10 g of each variety of beans per box in order to study the biology of the species according to each of those varieties.

3.2.3. Biological parameters studied

3.2.3.1 The duration of the development: It is the length of time that separates the egg-laying from the emergence of the resulting adults. Four boxes with 10 g of seeds are used for four simultaneous tests with each variety of beans. Ten weevils, 3 adults males and 7 females (taking into account the sex ratio) aged from 0 to 1 day, are put in each container et removed after 24 days of infestations. The seeds are left in incubation till the emergence of the first insect. These adult insects from each container are collected, numbered until there are no more emergences. The number of weevils emerged per day is noted down and the average development cycle of the insects is calculated on that basis.

3.2.3.2 The weight: The newly emerged adults have been numbered and weighed for each variety of beans with an S.A Sartorius scale of precision (max. = 4 g, d = 10^{-4} mg). The average weight of a weevil per variety of beans is calculated like this:

$$\text{Average weight of a weevil} = \frac{\text{Total weight of the weevils}}{\text{Number of weevil weighed}}$$

3.2.3.3 Longevity: is the life expectancy of adult weevils after their emergence. To study them, 40 couples of imagos per food support are isolated just after they emerge and fed on sugared water till they die. Every day, the individual dead ones are removed and numbered. The estimation of the average life expectancy or longevity of insects is the length of time between the emergence and the dying of the insect. It is determined by using the following formula:

$$\text{Average longevity } \frac{\Sigma\, xi\, ni}{\Sigma\, ni}$$

xi = life expectancies ; **ni** = number of dead insects

3.2.3.4 Fecundity determines the total number of eggs laid by the female. Forty couples isolated by food support are followed. After the death of the last insect, the eggs, both those on the sides of the boxes and on the seeds are numbered by means of binocular microscope. The resulting number of eggs is divided by the number of females (20) to have the average fecundity. That represents the total number of eggs the females lay during its life.

$$\text{Average fucundity } = \frac{\text{Total number of eggs}}{\text{Number of females}}$$

3.2.3.5 Fertility corresponds to the rate of emergence. The number of emerged adults per box is counted till there are no more emergences. The emergence rate is calculated the following way:

$$\text{Fertility} = \text{Rate of emergence} = \frac{\text{Total number of emerged adults}}{\text{Number of eggs}} \text{ X 100}$$

The sex ratio or feminity ratio, the separation of the basis of the sex has been done considering the basis of the characteristic of the antenna and the abdomens described by Halstead (1963). The sex ratio was determined by the number of males for every 100 females (Richards 1947). The feminity rate per food support is calculated this way:

$$\text{Sex} - \text{ratio} = \frac{\text{Number of females}}{\text{Total number of weevil } (\text{♀ et ♂})} \text{ X 100}$$

3.2.4. Statistic Analysis

Variance analysis and the multiple tests of NEWMAN and KEULS up to the level of 5% by means of the XLSTAT software have been used to compare the average of the different biologic parameters studied on the 5 varieties of beans used.

4. RESULTS

4.1. Physical-chemical and morphological characterization of the seeds of legumes: It stands out that the analysis of these values that the white cowpea IT97K499-38 is the most energetic variety with the highest level of proteins, of fat and of sugar with a thin tegument (Table 1).

4.2. Influence of varieties of tested beans on the biological parameters studied. : With the two varieties of *Phaseolus*, no descendant has been recorded, out of the 240 seeds infested by weevils. After the dissection of seeds, no larva has been observed**.** The eggs that have been laid on those seeds do not develop, so no emerged adult has been noticed and that can help study the biology of the weevils on these commodities. On the varieties of cowpea, some emergences have been observed.

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Table 1: Physical-chemical and morphological of the legume seeds

			Variety of tested legumes			
Characteristics	Phr	Phb	IT97K499-38	IT96D610	TVX1248	Probability (P)
Colour	Dark red	White	White	red	Purplish	-
Shape	± arched	± arched	± Rounded	Rounded	± cylindrical	-
Tegument	Thick and rough	Thick and rough	Thin and rough	Thin and smooth	Thin and smooth	-
Size (cm)	1.69 ± 0.15a	1.47 ± 0.27a	0.92 ± 0.15b	0.65 ±0.11c	0.58 ± 0.16c	0.013
Weight 100 seeds (g)	50± 0.02a	50± 0.01a	13± 0.08d	14± 0.91c	15± 0.02b	0.041
Humidity (%)	13.60± 0.11b	12.20± 0.17c	9.80± 0.12d	15.50± 0.11a	12.20± 0.09c	0.013
Cellulose (%)	5.33± 0.28b	5.00± 0.01b	3.33± 0.03c	6.33± 0.02a	6.67± 0.03 a	0.047
Proteins (%)	21.88± 0.02b	21.88± 0.04b	25.75± 0.81a	20.13± 0.07 c	20.88± 0.02 c	0.011
Fat (%)	1.80± 0.05d	2.00± 0.01c	2.60± 0.01a	2.00± 0.2 c	2.20± 0.05b	0.013
Starch (%)	33.80± 0.81d	36.52± 0.66b	43.38± 0.85a	37.50± 0.21b	35.32± 0.31c	0.001
Sugar (%)	4.38± 0.18c	4.70± 0.16b	5.22± 0.24a	3.73± 0.12d	4.70± 0.21b	0.013
Energy (Kcal/Kg)	1452.77± 1.15d	2591.35± 1.95b	2968.79± 1.55a	2535.49± 1.18c	2557.85± 1.36c	0.001

On the same line, the values bearing the same letters are not significantly different up to the level 5 % according to Newman and Keuls.

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4.2.1 . Influences of the tested varieties of cowpea on the duration of the development cycle of the *C. maculatus* (FAB.) : On the three varieties of *Vigna unguiculata*, no significant different were revealed by the statistic processing (p = 0.00012). However, the variety IT97K499-38, with average shorter development duration of 27.20 ± 0.14 days seems to differ from the other two 28.78 ± 1.73 and 28.66 ± 0.88 days on the red cowpea named IT96D610 and the purplish cowpea TVX1248 respectively by the rate of emerged individuals. On the variety of the white cowpea (IT97K499-38), the minimal duration of the cycle was 23 days and the longest is 32 days. But the highest number of weevils (36.6%) emerged after 27 days. On the variety of cowpea rouge (IT96D610), the minimal duration of the cycle was 24 days and the maximum was 34 days. However, the highest number of insects (24.7%) emerged on the 28th day. On the purplish cowpea (TVX1248), the minimal cycle minimal lasted 26 days, and the longest was 36 days. Moreover, the highest number of weevils (21%) emerged on the 28th day (Figure 2).

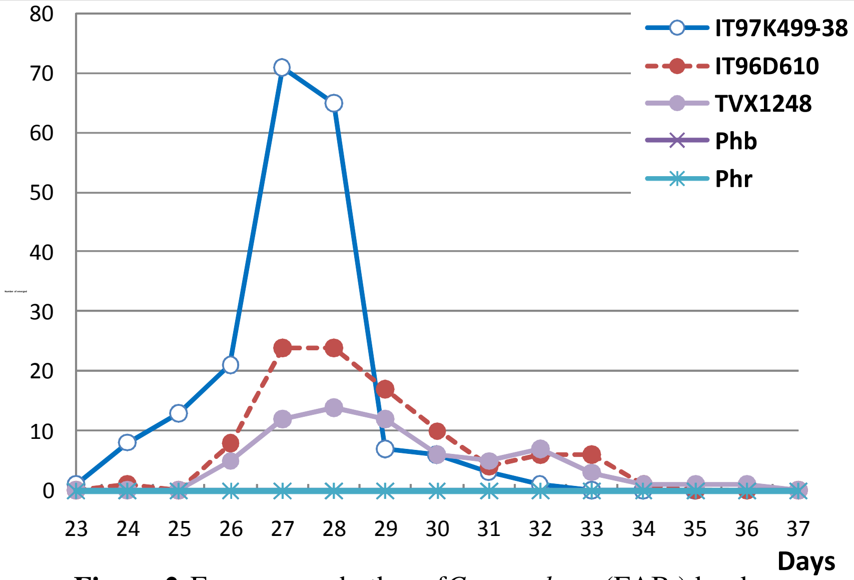

Figure 2: Emergence rhythm of *C. maculatus* (FAB.) bred on different varieties of beans

4.2.2. Influence of the tested varieties on the weight of the imagos of *C. maculatus* (FAB.): The variance analysis, followed by the comparisons of the averages show a significant difference (P = 0.032<0.05) between the weight of 3.48 ±0.29 mg, recorded on the variety IT97K499-38 and the two varieties with the values of 2.83±0.18 mg (cowpea, IT96D610) and 2.87±0.23 mg on the purplish (cowpea, TVX1248) (Figure 3).

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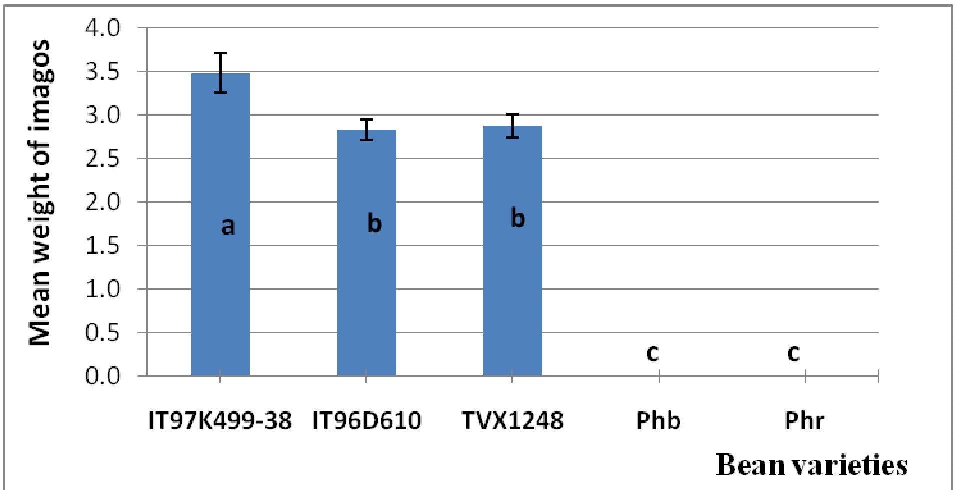

Figure 3: Mean weight of imagos of *C. maculatus* bred on different varieties of beans

Figure 3: highlights the highest mortality rate. On the variety IT97K499-38, all the insects die after the 6th day with a high level on the 4th day, on the purplish cowpea (TVX1248), all the insects die on the 8th day with the highest level on the 6th day. With the red cowpea (IT96D610), the dying occurred from between 4th and the 14th day after the emergence with highest levels on the 8th and the 13th days (Figure 4).

The statistics analysis help distinguish two classes of longevity values (Figure5). The longevity of the insects bred on red cowpea (IT96D610) significantly differs from that of the insects bred on the white cowpea (IT97K499-38) and on the purplish cowpea (TVX1248) with p = 0.001. The larval feeding has a significant effect on the life expectancy of the imagos of *C. maculatus*).

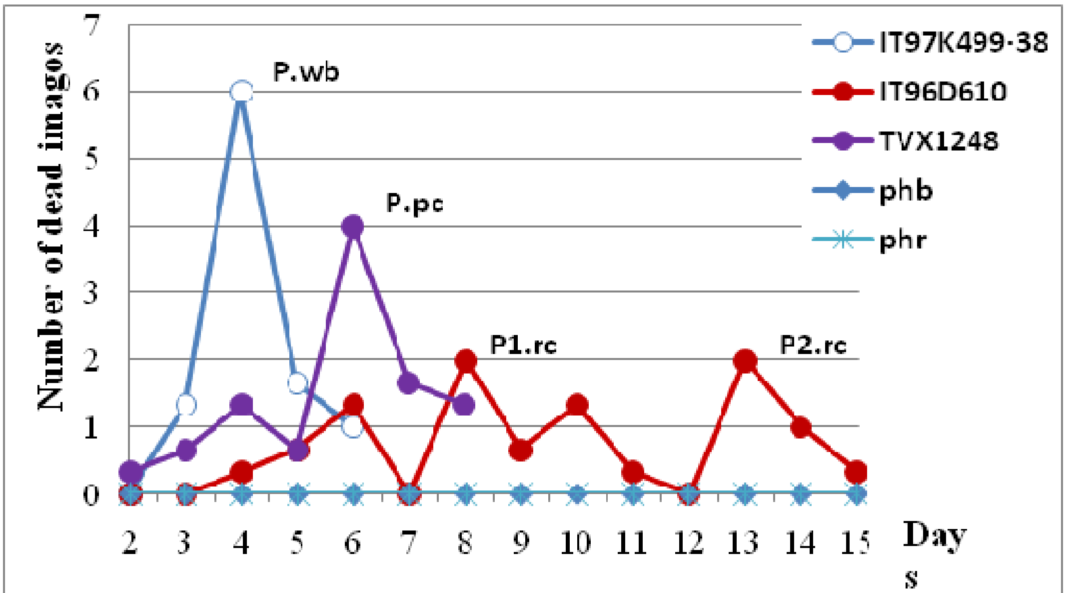

Figure 4: daily mortality of *C. maculatus* (FAB.) on the different varieties of beans

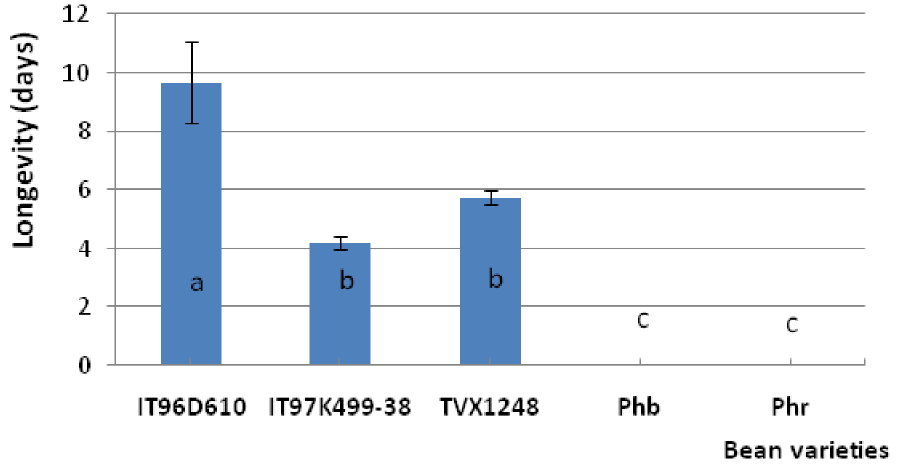

Figure 5 : Longevity of *C. maculatus* (FAB.) bred on different varieties of beans (p = 0.001)

4.2.4. Influence of the tested variety of the fecundity of *C. maculatus* (FAB): The average fecundity of the 54.75 ±1.2; 52.25±1.1 and of 56.25±1.6 on respectively the white cowpea varieties (IT97K499-38), red cowpea (IT96D610) and purplish cowpea (TVX1248**)**. The statistic analysis does not reveal any major difference (P = 0.070 > 0.05; F = 2.74; d.l. = 2.85) (Figure 6). Those small differences could be explained by the size, the aspect of the tegument of the seeds and the average longevity on each variety of food. Actually, the weevils prefer laying eggs on the seeds of the red cowpea (IT96D610) and on the purplish cowpea **(**TVX1248**)** because they provide a smooth surface (tegument) for egg-laying while the seeds of IT97K499-38 have a rough tegument.

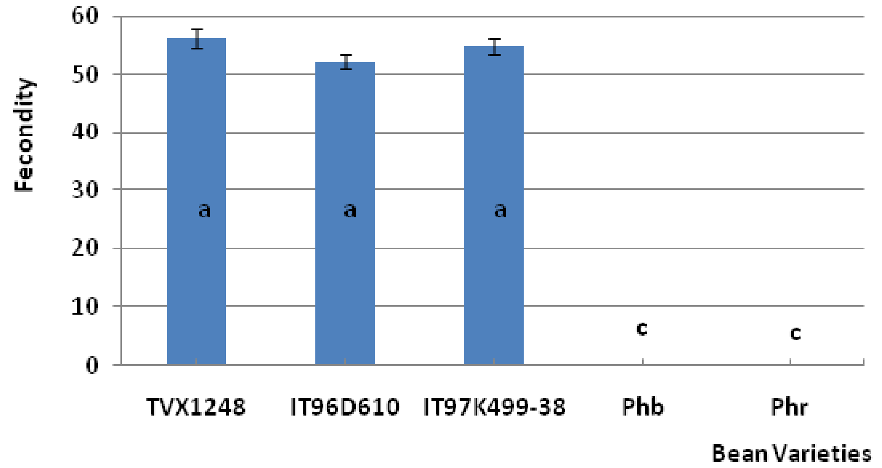

Figure 6 : Fecondity of *C. maculatus* (FAB.) according to the variety of beans by the larvae (p > 0,05).

4.2.5. Influence of the tested varieties of cowpea on the fecundity of the *C. maculatus* (FAB): The results show that the number of emerged individuals is higher on the cowpea IT97K499-38 (80.8%) than on the cowpea (IT96D610) and **(**TVX1248**)** (74.3 and 75.8%). The statistic analysis shows that there is a major difference between the three varieties (P = 0.0001 < 0.001; F = 49.25; d.l. = 2.85) (Table 2). In either case, the emergence rate is very high but does not reach 100%, no matter the variety.

Tableau 2: Average emergence rate of the *C. maculatus* according to the variety of cowpea consumed by the larvae

Variety of the cowpea	IT97K499-38	IT96D610	TVX1248	Phb	Phr
Total number of egg laid.	2190	2090	2250	2195	2188
Total number of eggs laid on the seeds	1150	1161	1240	1155	1145
Number of weevils emerged	930	863	940	0	0
Emergence rate or fertility	80,86 ±3,49a	74,33 ±4,54b	75,80 ± 3,09b	0	0

4.2.6. Influence of the tested varieties of the cowpea on the sex ratio or the feminity rate : The sex ratio is revealed by the number of males per 100 females is 85.20%, 85.15% and 85.07% on the cowpea IT97K49 9-38, IT96D610 and TVX1248 (Table 3).

Table 3 : Number of emerged larvae and the sex ratio per variety consumed by the larvae

Varieties of cowpea	IT97K499-38	IT96D610	TVX1248	Phb	Phr
Total number Of emerged weevils	196	101	67	0	0
Emerged males	29	15	10	-	-
Emerged females	167	86	57	-	-
Sex-ratio (%)	85,20 ± 1,12a	85,15 ± 1,24a	85,07±1,6a	-	-

The variance analysis shows that there is no significant difference (P = 0.440 > 0,05; F = 0.60; d.l. = 1, 170). The sex ratio is very high (85%) for females and does not depend on the food factors.

5 DISCUSSION

The results obtained from the different studied parameters reveal some variability due to morphological, and both physical-chemical characters of the legumesunder study. The two varieties of *Phaseolus* had a resistant effect because the eggs of *C. maculatus* could not grow. This resistance can be physical and linked to the morphology, the hardness and to the chemical component of the seeds that can make a good barrier against the penetration of the larva of *Callosobruchus maculatus* (FAB) (Dabiré *et al*., 2003; Schmale *et al*., 2003 ; Singh *et al*., 2004 ; Mensah, 2011). Moreover, with the leguminous plants, the presence of arcelin, a major protein has been identified as the causing factor of resistance to weevils of the beans (Schmale *et al*., 2003). Also, the beans *Phaseolus* were imported and could pose a problem to the weevil from Africa. On the 3 varieties of cowpea, there is no significant difference about the duration of the development cycle of the *Callosobruchus maculatus* (Delobel and Tran, 1993). But the chemical component of the three varieties shows that the white cowpea is richer in proteins than the other two with a rate of 25.5% and 20.88% in the red cowpea and the purplish cowpea respectively. These ratios could justify this gap caused by their trophic quality. The proteins are said to intervene on the duration of the different stages in the evolution of the weevil, acting directly on the inter-moult by shortening them (Luca, 1975). Giga and Smith (1985) working at a temperature of 30°C, on the *Vigna unguiculata* (L.) WALP experienced a reproductive cycle of 28 days with the *Callosobruchus maculatus* (PIC). On weight, the observations are consistent with those of Ali-Diallo (1991), Danho and Haubruge (2003) and that of Johnson *et al* (2013); the relatively low weight in values of the weevils bred on the red cowpea - IT96D610 and on the cowpea TVX1248 could be justified by the quantitative importance of the food resources on the biology of the insects with endogeneity development cycle. Moreover, the larval competition could be higher on the red variety that favours fewer egg with a lower level of nutrients than the white cowpea, variety IT97K499-38 the average size of the seeds being 0.58 and 0.92 respectively. Concerning the longevity, the difference between the noted results on the white cowpea and those obtained with the purplish cowpea can be justified by the length of the time of development longer than those of the last two and their content in energy. The density of the tegument of the resulting insect is said to be more important with content in cellulose twice higher in the cowpea IT96D610 and the purplish TVX1248 than in the variety of cowpea IT97K499-38. The cellulose is to be part of the component of the tegument (Montaigne, 1965). That would help the insects better withstand the living condition such as the drying up, and therefore live longer. Concerning the fecundity, this study results are consistent with those of Agbaka (1990) who showed that with the

Callosobruchus maculatus (FAB.), the laying grew with the longevity, and the maturity of the ovariols depend on the length of time that the larvae needs for their development. On the variety of the purplish cowpea, where the highest fecundity was noted, the average length of time is relatively higher (5.77 days). Moreover, the seeds of varieties such as IT96D610 and TVX1248 favour an average length of time higher (9.67 and 5.77 days) for 4.23 for the variety IT97K499-38; that is likely to increase the duration of the egg-laying by weevils. Giga and Smith (1985), and Johnson *et al* (2013) showed that the food on which the insects developed has an impact on the egg lay. Likewise, the amino-acids necessary for a better growth are also necessary for the development of the yolk and for the normal functioning of the female. Delobel and Tran (1993) showed that the average fecundity of the *Callosobruchus maculatus* is 54 eggs when the best conditions are provided. According to Montaigne, 1965, the food parameters could act by determining the quantity of provision available for the vitellogenesis. About the fecundity, the rates between 74% and 81% recorded at 24.43 ± 0.82°C are closer to those of Giga and Smith (1985) who noted that 78.1% to 30°C on *Vigna unguiculata* (L.) WALP. Those differences can be explained by the larval trophic competition within the same seed and the action of the potential parasites of the eggs or the larva, the size of the seeds relatively bigger of the variety IT97K499-38 of the cowpea as well as its richer content in proteins, in sugar and in energy compared with the other two varieties (Ouédraogo *et al.,* 2010, Doumma *et al.*, 2011). Moreover, the level of humidity affects the survival and the general development of the larva. The general development conditions of the larva are less favourable with the varieties IT96D610 and TVX1248 (15.50% and 12.20% d'H.R) leading to a higher death rate. This conclusion was also made by Singh and Singh (1992), they showed the high level of the content in water of the seeds on the biology of *C. maculatus* (FAB.).

The sex ratio does not change, no matter the food support. This observation was made by Motto (1995). He studied the *Callosobruchus chinensis* (L.) under several varieties. With that species, the level of females was apparently equal with that of the males, while with the *C. maculatus*, the sex-ratio is very high with the females and is 8/10.

6. CONCLUSION

The morphological characters of the seeds and their chemical content play an important role in the biology of the *Callosobruchus maculatus*. Actually, whether the development period, the weight of the insects, their fecundity, the white cowpea (*Vigna unguiculata Walp*, varieties IT97K499-38), very rich in protein and in sugar proved to be more favourable to the development of the weevils. Those parameters are important element of proliferation of the insects in the storage, therefore, a problem for the food self sufficiency in African countries. As for the *Phaseolus,* the density and the texture of their tegument could be the parameters causing their resistance the rejection by the weevil, as source of food or laying site, and with the absence of choice. That resistance of the two varieties of *Phaseolus*, could make room for a relevant genetics study so as to select the variety of leguminous plant which are less sensitive to the weevils, in order to reduce the loss during the storage and the conservation of the seeds. The withstanding mechanism to the weevils of the *Phaseolus* (physically, chemically, and genetically) combined with other of rationale ways could be an effective means to control *C. maculatus* and others insects in the stored commodities in general.

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