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RESEARCH ARTICLE

MORPHOMETRIC CHARACTERIZATION OF *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) INFESTING DIFFERENTS MAIZE VARIETIES IN WEST AND CENTRAL AFRICA.

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Zea mays; agro ecological zones; *Sitophilus zeamais*; morphometric groups; *West and central Africa.*

Abstract

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Maize (*Zea mays*) is a cereal cultivated in different agro-ecological zones. However corn is attacked by pest as *Sitophilus zeamais*. The latter can cause qualitative and quantitative losses ranging from 30 to 56% in three to eight months of storage. These losses caused by *S. zeamais* are often difficult to estimate because of their large variability that can be linked to the agro-ecological conditions, to the period of the corn harvest. In Africa, *S. zeamais* is particularly common on corn. While the biodemographiques characters affect the biological effect of the insect.

Thus, this study in to determine the existence of groups of *S. zeamais* morphometric some countries of West and central Africa. This sample of maize previously infected with *S. zeamais* in these different countries. The results have revealed the existence of morphometric groups between some of the countries in the study.

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Introduction:-

Maize (Zea mays, family of the Poaceae) is a cereal cultivated in various agro ecological zones, alone or in combination with most cultures (Escalente *et al.*, 2012). Its production to get through periods of welding in rural areas. However, corn is attacked from the field and during storage by pest as *Sitophilus zeamais* (Motschulsky). This primary pest of corn can cause qualitative and quantitative losses ranging from 30 to 56% in three to eight months storage (Ngamo *et al.*, 2007). Thus, it promotes colonization of stocks by secondary pests and producing fungi such as *Aspergillus flavus* toxin (Gueye *et al.*, 2011). This different damage reduces the quality of the grain and renders it unfit for consumption (Waongo *et al.*, 2013). However, the estimate of losses caused by s. zeamais is often difficult because of their variability that can be attached to the agro ecological conditions, the harvest period (Delobel and Tran, 1993) and Ngamo *et al.*, 2007). *Sitophilus zeamais* is a cosmopolitan insect very adapted to temperatures and high humidity [5]. It is widely distributed in tropical regions where it attacks the crops on foot (Anonyme, 2013). In

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Africa, it is particularly common on corn (Delobel and Tran, 1993). However, some countries in Africa have climatic and agro ecological conditions different from the other.

While the biodemographiques characters affect the biological effect of the insect (Danho and Haubruge, 2003). In addition to this environmental factors, including agronomic practices (types of fertilizers, farming practices), influence on the composition of grain (FAO, 1998) which in turn can influence the morphology until even the genetics of the insect population which infests him as the case of *Caryedon serratus* (Sembène, 2000). This context has led us to consider first whether *S. zeamais* has the same morphology at the level of the different agro ecological zones in West Africa and Central Africa where maize is grown in large quantities.
In order to meet this scientific question, this study aims to determine the existence of groups of *S. zeamais* morphometric in some countries in Africa, West and Central Africa.

Material and methods:-

Sampling:-

Areas of study have been selected according to the producers of corn, the infestation, taking into account the geographical position. Thus, the sampling was done in six West African countries and two countries in Central Africa specifically to the:

- Senegal 12 ° 00' - 16 ° 30' North and 11 ° 30' - 17 ° 30' West (West Africa);
- Guinea Conakry 7 ° 05' - 12 ° 51' North and 7 ° 30' - 15 ° 10' West (West Africa);
- Mali 10 ° - 25 ° North and (4) is - 12 ° West (West Africa);
- Side of ivory 4 ° 30' - 10 ° 30' North and 2 ° 30' - 8 ° 30' West (West Africa);
- Niger 12 ° - 23 ° North and 0 ° - 16 ° is (West Africa);
- Ghana 4 ° 44' - 11 ° 11' North and 1 ° 11' East - 3 ° 11' West (West Africa);
- Cameroon 2 ° - 13 ° North and 9 ° - 16 ° is (Central Africa);
- South Africa 3 ° - 11 ° North and 14 ° - 27 ° is (Central Africa).

In our sampling strategy, collections of maize were performed at the level of the places of storage of these countries and put in plastic bags. These are reduced to the insectariums and transferred in jars, in order to increase the population sampled by a second generation. The insect pests (*Sitophilus zeamais*) are subsequently collected in the laboratory and stored in 96 ° alcohol. Each individual sample is coupled with a code, by using the first letter of the genus name followed capitalize the first two letters of the country of origin (the first letter uppercase and lowercase second), of the variety of color and finally an order number. For example the code SSeY1 represents an individual of Sitophilus of Senegal, with as the number of order 1 (table 1).

Morphometric study:-

The biological material used for morphometric is composed of males of Sitophilus zeamais who were raised in jars after sampling of corn. The use of males for the morphometric study explained that females gravites change of morphology and can skew measurements. Of the male over the female are identified based on criteria set by the study of Delobel and Tran (1993) on insects for food. The insect is out of alcohol by a clamp, put in distilled water, then transferred on paper to be dried (the paper sucks the water in which the insect is soaked). It is then placed on a graph paper on a binocular magnifying glass, to carry out the measurements. The insect is first dissected with tweezers, separating his three parts namely the head, the thorax, and the abdomen. Each part is subsequently separated from his different articles. A total of 16 variables are measured with a degree of reasonable accuracy (table 2).

Statistical Analyses:-

Raw measurements:-

After the choice of the number of lines to remember, a discriminate factorial analysis (AFD) of the populations with the raw measurements of the variables by country (ecotypes) and the colors of the sampled corn has been produced with the software version 3.2.3 Bloomfield R (2014). Its purpose is to get out the contribution of the variables on each factorial axis, view correlations between variables and identify groups of individuals having taken values close on some variables based on these factors (country and color of the kernels of corn). For raw measurements, a Tukey test was done to determine the variables that allowed discrimination of populations.

Processed measurements:-

- **Effect size and data transformation:-**

The size effect translates into a circle of correlation which includes all the variables in a single plane for a given axis. It is an unwelcome effect, which metric studies are seeking to escape (Santos, 2015). The principles therefore eliminate this effect and bring everyone the same size, so I didn't observe on the CPA that differences in form. The elimination of the effect size in this study was conducted according to the approach proposed by Santos (2015):-log-transformation of data: our original data table consists of the variables X 1, X 2,..., Xp, we subsequently created a new data table made up of variables log (X 1), log (X 2),..., log (Xp);
-for each individual, we calculated the average of all the log-transformed variables. We believe that the average score is a good idea of the 'size' for this individual;
-Finally, for each individual, we cut to each of these raw measurements the average obtained with the log-transformed.

The effect size is thus eliminated, and only the difference of form will be observed on the ACP. The decrease in the weight of the factor (size) leads to a decline in overall discrimination between populations. This transformation was carried out under Excel version 2010.

Discriminate factorial analysis:-
A discriminate factorial analysis (AFD) of populations with the transformed data from variables by country (ecotypes) and the color of the sampled corn has been produced with the software version 3.2.3 Bloomfield R (2014). It is designed to get out the contribution of variables following the two axes and check if the same groups of individuals are identified on the basis of these factors (countries and of the variety of the maize).

Factorial analysis of correspondences (AFC):-
The factorial analysis of correspondences (AFC) is a method of multivariate analysis used most often in population genetics. This method considers the allelic frequencies in all populations at the various loci as variables (Hoda and Marson, 2012). In our morphometric study, we have transformed our variables in the form of loci to test possible metric similarities between populations and detect morphometric groups. Accordingly, a graphic representation is generated from measurements transformed and adapted using the program Genetix version 4.05.2 (Belkir *et al*., 2004).

Matrix of confusion for the results of cross-validation:-
The confusion matrix summarizes the reclassifications of individuals to deduce the rate of good and bad ranking. This allows determining the "% correct" which is the ratio of the number of ranked individuals, on the total number of individuals. Cross-validation is done using the transformed data depending on the country (ecotypes) and the color of the kernels of corn sampled with the XLSTAT version 2016.03.30882 software.

Hierarchical ascending Classification (CAH):-
The hierarchical ascending classification allows re-tooled to classes that are not obvious at first glance. She is to group individuals according to their resemblance and separate them according to their dissimilarity. The bottom-up classification was conducted with the XLSTAT version 2016.03.30882 software.

Structure morphometric:-
To search for independent morphometric (K) groups and assign each individual to a group, we used the software Structure version 2.3.4 (Prichard *et al.*, 2000). This program uses the Bayesian Markov Chain Monte Carlo (MCMC) approach, which is based on the model of clustering to infer the structure of morphometric populations and check the correct assignment of individuals to their population of origin according to a certain probability Q (multidimensional vector that represents the proportion of ancestry for all members of a population).

Results and discussion:-

Results:-

Raw measurements:-

Choice of the number of axes to remember:-
To get the number of lines to remember, we used the criterion of the elbow. This criterion is intended to get the most out of inertia kept with the minimum of factors. In our study, two axes are retained, as the break instead to K = 2 (figure 1).

Table 1:- summary table of sampling.

Pays	Number of sample	Sample code
Senegal	10	SSe
Guinea Conakry	10	SGu
Mali	10	SMa
Côte d'Ivoire	10	SCo
Niger	10	SNi
Ghana	10	SGa
Cameroon	10	SCa
The Central African Republic	10	SRe

Table 2:- measured variables

Measured variables		
Head	**Thorax**	**Abdomen**
Length of the rostrum (Lr) Width of the rostrum (Lar) Length of the antenna (Lan)	Length of the pronotum (Lop) Width of the pronotum (Lap) Length of the wing (Loa) Width of wing (Laa) Length of the Elytron (Loe) Width of the Elytron (Lae) Length 3 tibia (LT3) Length 3 femur (Lf3) Length coxa 3 (Lc3) Length Tarsus 3 (Lt3)	Width pygidium (lpy) Thickness pygidium (Epy) Length of the first sternum (Los1)

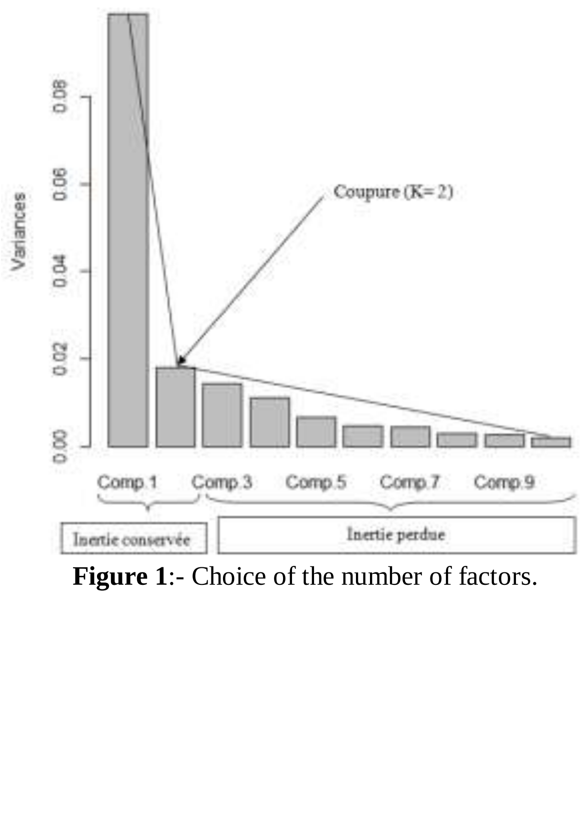


Figure 1:- Choice of the number of factors.

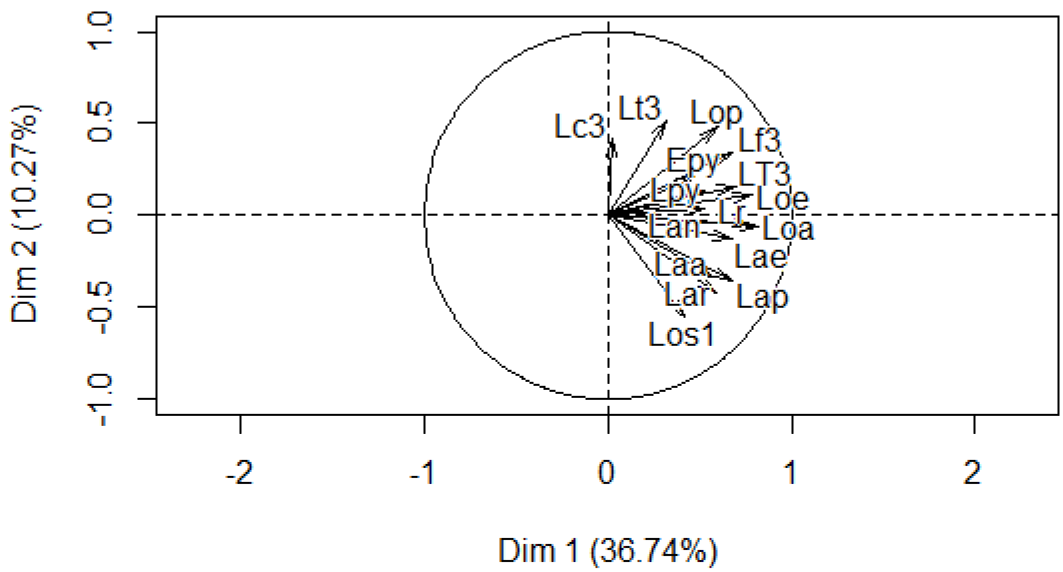


Figure 2:- distribution of the variables according to their contribution to the construction of the two dimensions (Dim 1 and Dim 2) with the raw data.

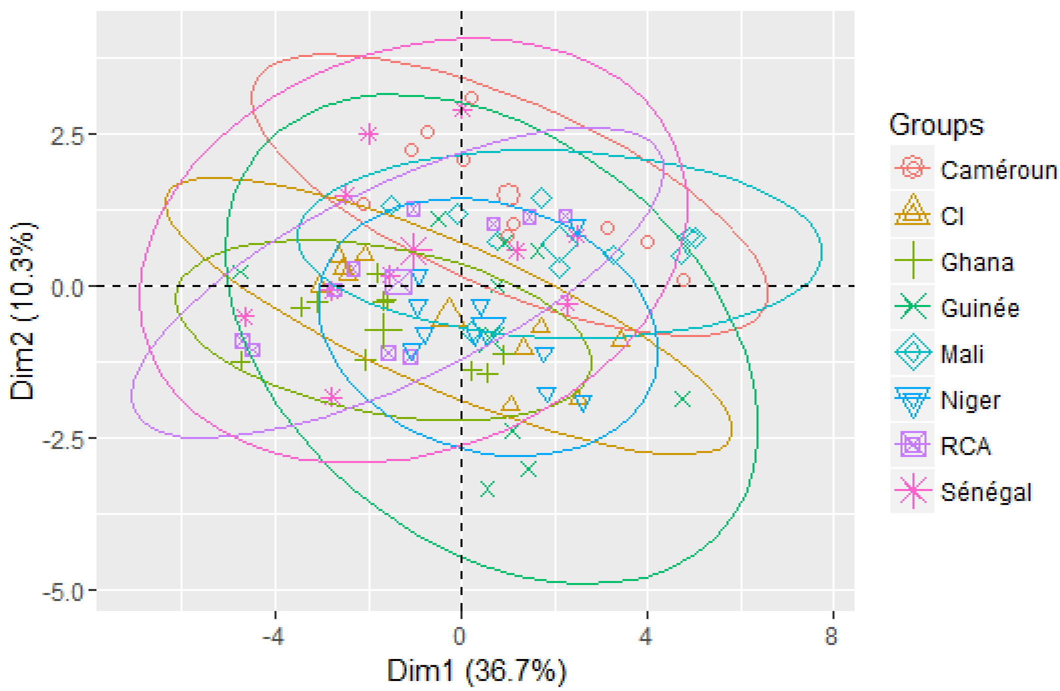


Figure 3:- Representation in the main plan of the AFD of the populations of *Sitophilus zeamais* defined according to the countries sampled.

Table 3:- Test Tukey-Kramer based on the ecotypes

Ecotype variable	**Cameroun**	**Côte d'Ivoire**	**Ghana**	**Guinea Conakry**	**Mali**	**Niger**	**RCA**	**Senegal**
Lr	1.57 ± 0.08^{b}	1.50 ± 0.10^{ab}	1.54 ± 0.08^{ab}	1.56 ± 0.06^{b}	1.58 ± 0.10^{b}	1.53 ± 0.08^{ab}	1.43 ± 0.10^{a}	1.53 ± 0.11^{ab}
Lar	0.52 ± 0.04^{a}	0.55 ± 0.05^{a}	0.54 ± 0.052	0.56 ± 0.07^{a}	0.55 ± 0.07^{a}	0.52 ± 0.04^{a}	0.50 ± 0.00^{a}	0.50 ± 0.08^{a}
Lan	1.04 ± 0.05^{b}	1.00 ± 0.00^{ab}	0.97 ± 0.05^{a}	1.04 ± 0.07^{b}	1.08 ± 0.04^{c}	1.02 ± 0.04^{ac}	1.01 ± 0.03^{ab}	1.03 ± 0.07^{ac}
Lop	1.42 ± 0.04^{d}	1.23 ± 0.05^{a}	1.23 ± 0.07^{a}	1.28 ± 0.04^{ab}	1.41 ± 0.06^{c}	1.36 ± 0.07^{bc}	1.32 ± 0.09^{ac}	1.33 ± 0.08^{bc}

Lap	1.09±0.10^{a}	1.07±0.08^{a}	1.06±0.05^{ab}	1.11±0.09^{a}	1.13±0.07^{b}	1.14±0.07^{b}	1.11±0.06^{ab}	1.02±0.06^{a}
Loa	3.44±0.20^{a}	3.42±0.31^{a}	3.18±0.22^{a}	3.57±0.23^{b}	3.62±0.26^{c}	3.43±0.22^{ac}	3.23±0.26^{a}	3.29±0.13^{ab}
Laa	1.06±0.18^{a}	1.22±0.06^{b}	1.17±0.07^{ab}	1.11±0.12^{a}	1.22±0.08^{b}	1.15±0.12^{ab}	1.07±0.10^{ab}	1.02±0.18^{a}
Loe	1.85±0.07^{a}	1.78±0.09^{a}	1.77±0.05^{a}	1.85±0.11^{a}	1.87±0.11^{a}	1.88±0.06^{a}	1.77±0.09^{a}	1.79±0.10^{a}
Lae	0.84±0.05^{a}	0.84±0.05^{a}	0.79±0.03^{a}	0.88±0.12^{b}	0.86±0.05^{a}	0.88±0.04^{b}	0.81±0.06^{ab}	0.84±0.05^{ab}
LT3	0.78±0.04^{a}	0.77±0.04^{a}	0.71±0.06^{a}	0.75±0.37^{a}	0.74±0.05^{a}	0.74±0.05^{a}	0.70±0.08^{a}	0.71±0.06^{a}
Lf3	1.00±0.00^{b}	0.95±0.05^{a}	0.91±0.06^{a}	0.95±0.05^{a}	0.98±0.05^{a}	0.95±0.05^{ab}	0.92±0.08^{ab}	0.93±0.09^{ab}
Lc3	0.30±0.00^{a}	0.30±0.00^{a}	0.30±0.00^{a}	0.28±0.04^{a}	0.30±0.02^{a}	0.30±0.00^{a}	0.30±0.00^{a}	0.29±0.03^{a}
Lt3	0.60±0.07^{b}	0.58±0.04^{a}	0.55±0.05^{ab}	0.57±0.07^{a}	0.57±0.05^{a}	0.52±0.04^{a}	0.54±0.052^{a}	0.53±0.06^{ab}
Lpy	0.51±0.12^{a}	0.51±0.03^{a}	0.47±0.05^{a}	0.50±0.07^{a}	0.64±0.05^{b}	0.52±0.04^{a}	0.55±0.07^{ab}	0.56±0.05^{ab}
Epy	0.84±0.05^{b}	0.78±0.04^{a}	0.77±0.05^{a}	0.79±0.06^{a}	0.84±0.05^{b}	0.76±0.05^{a}	0.80±0.00^{ab}	0.81±0.06^{ab}
Los1	1.03±0.05^{a}	1.05±0.05^{a}	1.04±0.05^{ab}	1.05±0.05^{a}	1.02±0.04^{a}	1.08±0.04^{b}	1.04±0.05^{ab}	1.01±0.03^{a}

Table 4:- Test Tukey-Kramer based on the ecotypes after data transformation

Ecotypes variables	Cameroun	Côte d'Ivoire	Ghana	Guinea Conakry	Mali	Niger	RCA	Senegal
Lr	1.59±0.07^{b}	1.53±0.09^{a}	1.58±0.08^{b}	1.58±0.06^{b}	1.59±0.09^{b}	1.56±0.07^{a}	1.47±0.05^{a}	1.57±0.10^{ab}
Lar	0.54±0.03^{a}	0.58±0.04^{a}	0.58±0.04^{a}	0.56±0.06^{a}	0.55±0.03^{a}	0.54±0.02^{a}	0.54±0.02^{a}	0.54±0.07^{a}
Lan	1.06±0.05^{a}	1.03±0.02^{a}	1.01±0.04^{a}	1.07±0.06^{a}	1.09±0.03^{b}	1.05±0.04^{a}	1.05±0.03^{a}	1.07±0.07^{ab}
Lop	1.44±0.03^{d}	1.26±0.03^{a}	1.27±0.05^{a}	1.30±0.04^{a}	1.42±0.06^{cd}	1.39±0.07^{c}	1.36±0.07^{b}	1.37±0.07^{bd}
Lap	1.11±0.08^{a}	1.10±0.06^{a}	1.10±0.05^{a}	1.14±0.08^{a}	1.14±0.05^{a}	1.17±0.06^{b}	1.15±0.06^{a}	1.06±0.04^{a}
Loa	3.46±0.18^{a}	3.45±0.29^{a}	3.22±0.21^{a}	3.6±0.22^{b}	3.63±0.25^{b}	3.46±0.22^{a}	3.27±0.24^{a}	3.33±0.11^{ab}
Laa	1.08±0.16^{a}	1.25±0.05^{c}	1.21±0.05^{b}	1.14±0.11^{a}	1.23±0.06^{b}	1.18±0.11^{a}	1.11±0.09^{a}	1.06±0.16^{a}
Loe	1.87±0.06^{a}	1.81±0.08^{a}	1.81±0.04^{a}	1.88±0.06^{a}	1.88±0.10^{a}	1.91±0.06^{a}	1.81±0.08^{a}	1.83±0.09^{a}
Lae	0.86±0.04^{a}	0.87±0.04^{a}	0.83±0.02^{a}	0.91±0.10^{b}	0.87±0.04^{a}	0.91±0.04^{b}	0.85±0.05^{a}	0.88±0.03^{ab}
LT3	0.80±0.04^{a}	0.80±0.04^{a}	0.75±0.05^{a}	0.78±0.08^{a}	0.75±0.04^{a}	0.77±0.04^{a}	0.74±0.06^{a}	0.75±0.05^{a}
Lf3	1.02±0.02^{a}	0.98±0.04^{a}	0.95±0.05^{a}	0.98±0.06^{a}	0.99±0.04^{a}	0.98±0.04^{a}	0.96±0.06^{a}	0.97±0.08^{a}
Lc3	0.32±0.02^{a}	0.32±0.02^{a}	0.34±0.01^{b}	0.31±0.05^{a}	0.31±0.02^{a}	0.33±0.01^{a}	0.34±0.02^{a}	0.33±0.03^{ab}
Lt3	0.62±0.05^{b}	0.60±0.05^{a}	0.59±0.05^{a}	0.58±0.07^{a}	0.58±0.04^{a}	0.55±0.04^{a}	0.58±0.03^{a}	0.57±0.05^{ab}
Lpy	0.53±0.10^{a}	0.54±0.03^{a}	0.51±0.03^{a}	0.53±0.05^{a}	0.65±0.04^{c}	0.55±0.05^{a}	0.59±0.06^{a}	0.60±0.04^{bc}
Epy	0.86±0.41^{b}	0.81±0.04^{a}	0.81±0.04^{a}	0.82±0.04^{a}	0.85±0.04^{b}	0.79±0.05^{a}	0.84±0.02^{a}	0.85±0.06^{b}
Los1	1.05±0.04^{a}	1.08±0.04^{a}	1.08±0.04^{a}	1.08±0.05^{a}	1.03±0.04^{a}	1.11±0.05^{b}	1.08±0.05^{a}	1 ;05±0; 03^{a}

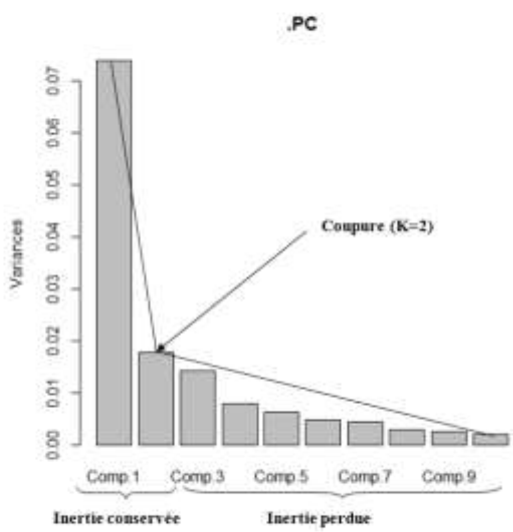


Figure 4:- Choice of the number of factors after the data transformations.

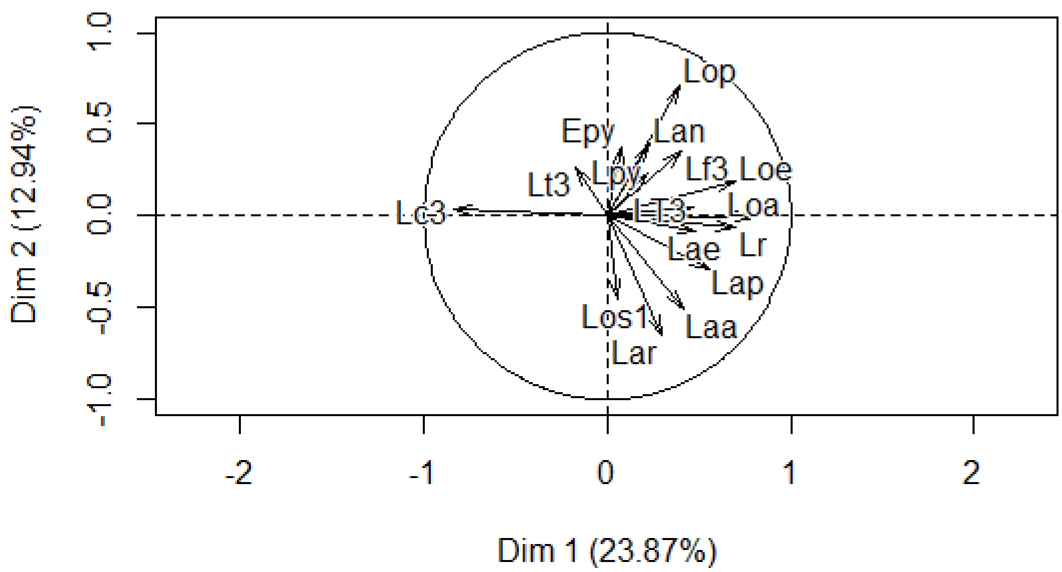


Figure 5:- Distribution of the variables according to their contribution to the construction of the two dimensions (Dim 1 and Dim 2) with the transformed data.

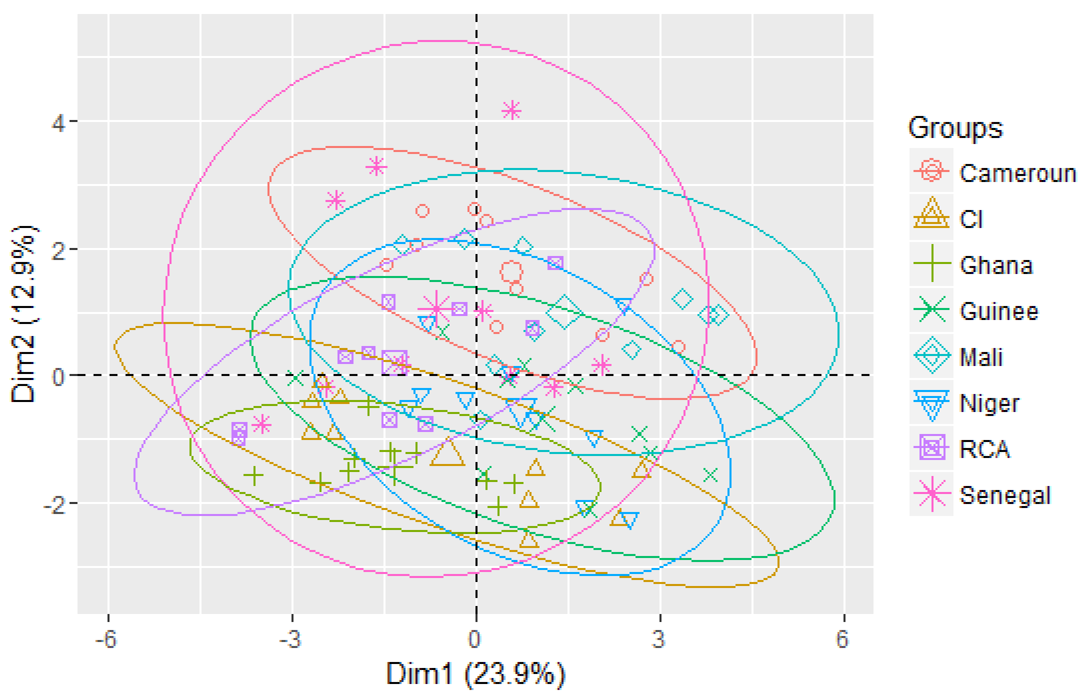
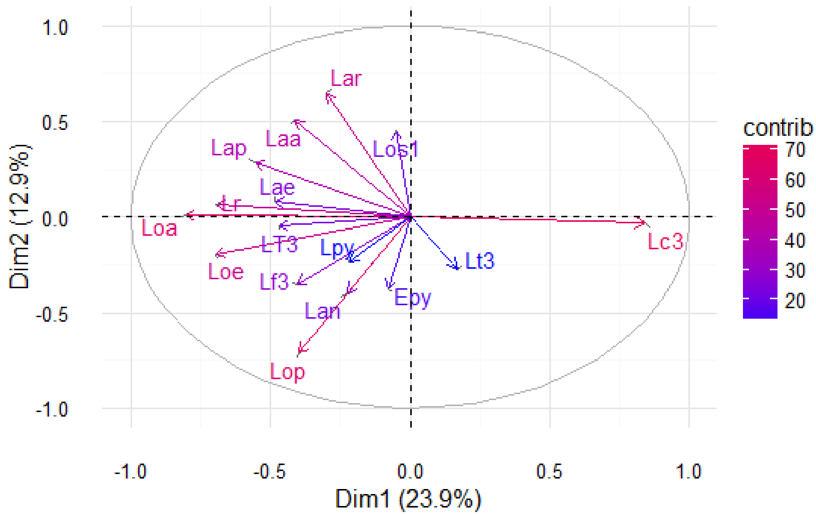
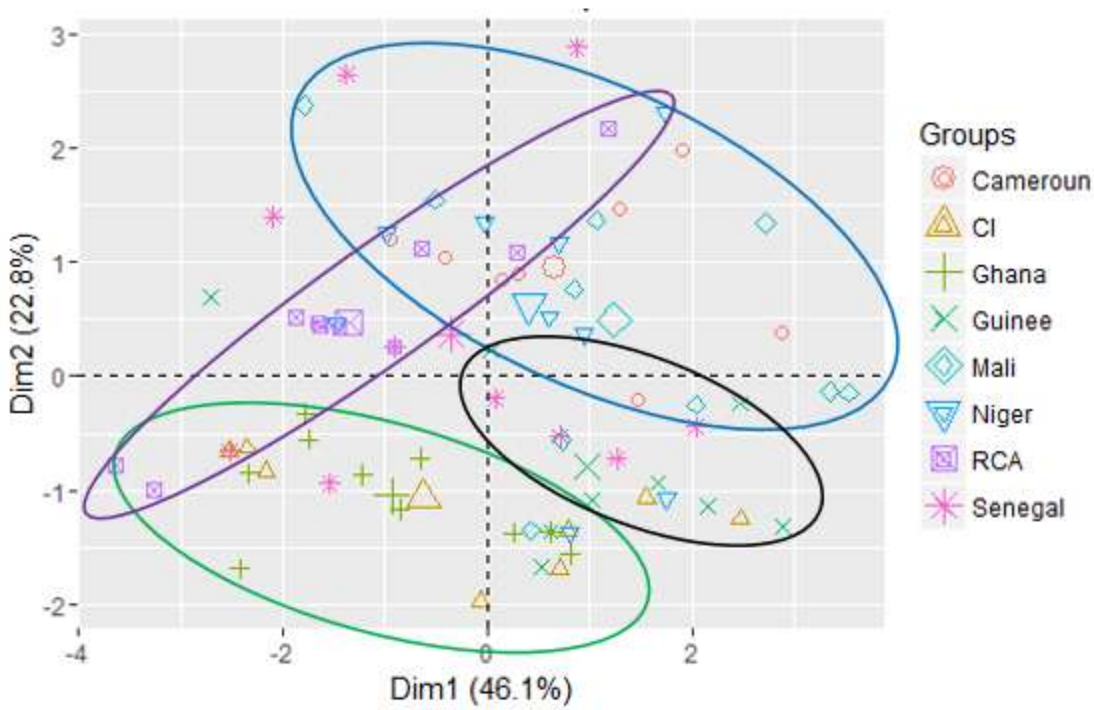


Figure 6:- Representation in the main plan of the AFD of the populations of *Sitophilus zeamais* defined according to the countries sampled after processing of the survey.



A



B

Figure 7:- the most discriminating variables (A); the discriminate factorial analysis (AFD) of the populations with the most discriminating (B) variables.

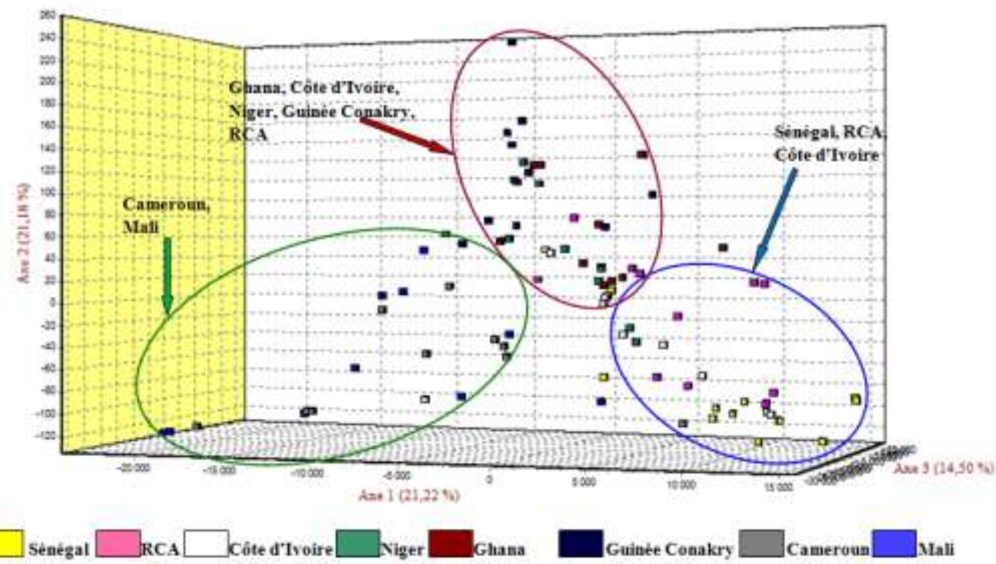


Figure 8:- distribution of the randomness morphometric ecotypes following the first 3 lines of the AFC.

Table 5:- matrix of confusion for the results of cross-validation of ecotypes.

De/vers	Côte d'Ivoire	Cameroun	Ghana	Guinéa Conakry	Mali	Niger	RCA	Senegal	Total	%correct
Côte d'Ivoir	**2**	0	2	1	2	1	2	0	10	**20%**
Cameroun	0	**7**	0	0	1	0	2	0	10	**70%**
Ghana	0	0	**4**	2	3	0	1	0	10	**40%**
Guinea Conakry	1	0	0	**9**	0	0	0	0	10	**90%**
Mali	0	2	0	0	**8**	0	0	0	10	**80%**
Niger	1	1	0	0	0	**5**	2	1	10	**50%**
RCA	0	2	0	0	0	1	**7**	0	10	**70%**
Senegal	0	1	0	2	0	0	1	**6**	10	**60%**
Total	**4**	**13**	**6**	**14**	**14**	**7**	**15**	**7**	80	**60%**

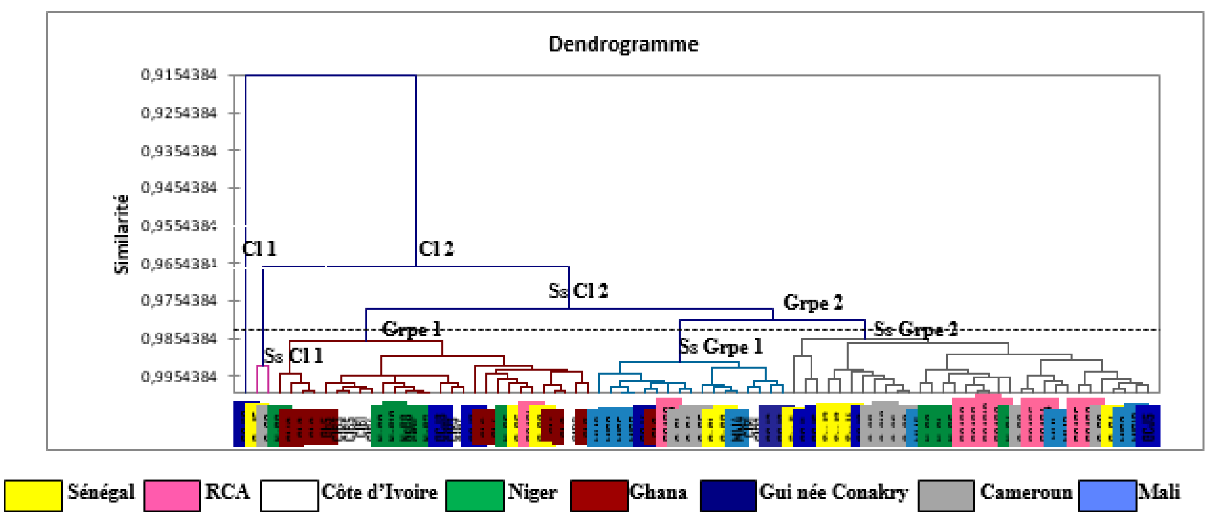


Figure 9:- Hierarchical ascending Classification by similarity based on the ecotypes.

Cl1: Class1; Cl2: class 2; SS Cl1: sub class 1; SS Cl2: under navies 2; Grpe 1: group1; Grpe 2: Group 2. SS Grpe 1: under Group 1; SS Grpe 2: under Group 2.

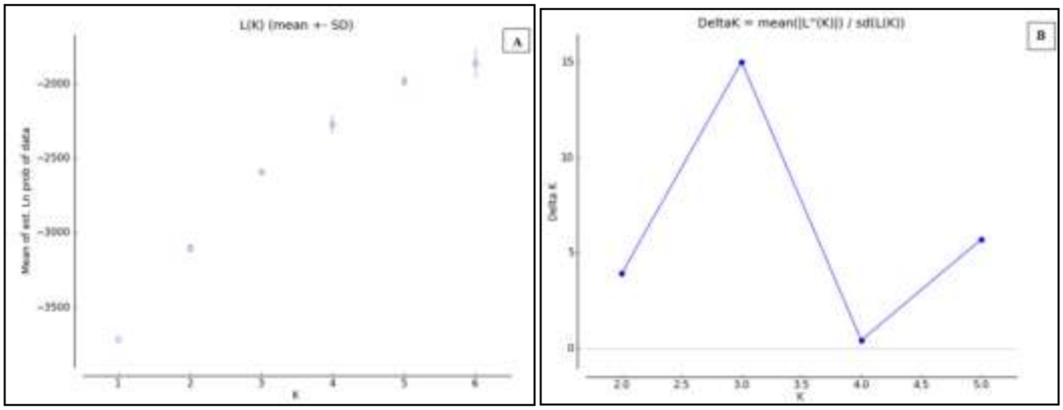


Figure 10:- Medium-sized posterior probability (L (K)) of the different values of K (A); the method of Evanno (B).

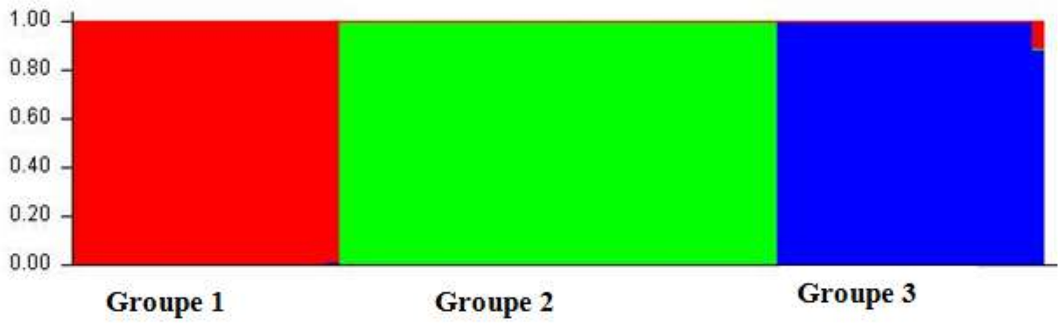


Figure 11:- Assignment of individuals to morphometric groups.

Contribution of the variables with their raw measurements:-

The discriminate factorial analysis reveals that the first two factorial axes (dimensions) explain at best with 47. 01% morphometric variability to inertia. Variables such as Loa (F1 = 11.5), Loe (F1 = 10.5), Lr (F1 = 10.3), LT3 (F1 = 8.3), Lf3 (F1 = 7. 9), Lae (F1 = 7. 72), Lap (F1 = 8.46), Lop (F1 = 6.20), Lar (F1 = 6) and Laa (F1 = 5. 6) are widely involved in construction of the first factorial axis with 36.74% of the inertia power (Figure 2). Others such as Lpy (F1 = 4. 8), Lan (F1 = 4. 7), Epy (F1 = 3.83), Los1 (F1 = 3.01), Lt3 (F1 = 1. 7) and (F1 = 0.008) Lc3 weakly contribute to the construction of this factorial axis. The axis factorial two with a low inertia power (10.27%) is built by variables Los1 (F2 = 18. 8), Lt3 (F2 = 16. 4), Lop (F2 = 14), Lar (F2 = 10.7), Lc3 (F2 = 10.6), Lap (F2 = 7.76), Lf3 (F2 = 7.05) and Laa (F2 = 6.88). Other variables such as Epy (F2 = 2.8), LT3 (F2 = 1.56), Lpy (F2 = 1.12), Lae (F2 = 1.04), Loe (F2 = 0.72), Loa (F2 = 0.20), Lr (0.12) and Lan (F2 = 0.09) weakly contribute to the construction of this axis. On the first factorial axis variables are positively correlated, because they have the same sign. Obviously the effect size has affected our ACP (Figure 2).

Discrimination of people based on the ecotypes:-

The highest quality of representation is obtained by the plan formed by the two first axes (Dim1 and Dim2) with 45.7% of the inertia power (Figure 3). Taking account of the redeployed to each ecotype, following the first factorial axis (Dim1), variables that have participated in the construction of this axis, have allowed low discrimination of the Côte d'Ivoire ecotype, ecotype Ghana, the RCA ecotype and ecotype Senegal, other ecotypes (Cameroon, Mali, Guinea Conakry and Niger) with areas of very important introgressions (Figure 3). On the second factorial axis, Cameroon and Mali ecotypes to discriminate weakly ecotypes Niger and Guinea Conakry. While the RCA and Senegal ecotypes differ weakly Ghana and Côte d'Ivoire ecotypes with areas of significant overlap (Figure 3).

Variables to the discrimination of the ecotypes:-

The variables allowing the discrimination of the ecotypes are determined by the Tukey-Kramer test. This test is to compare the average of each variable between ecotypes to determine the variables that allow discriminating against people.

On the first factorial axis, low discrimination of the Mali ecotype with the ecotypes of Côte d'Ivoire, Niger, Guinea Conakry and Cameroon is due to the length of the pygidium (Lpy). For the Mali ecotype and the RCA ecotype, these are variables, the length of the rostrum (Lr) and the length of the wing (Loa), which allowed low discrimination. As for the discrimination of the Senegal ecotype and the Mali ecotype, variables, the width of the pronotum (Lap) and the width of the wing (Laa), are originally. The discrimination of the Mali ecotype and the ecotype Ghana, these are variables, the length of the antenna (Lan), the length of the wing (Loa), the length of the pygidium (Lpy) and the thickness of the pygidium (Epy) who are originally. While the Elytron (Lae) width and length of the pronotum (Lop) distinguishes the ecotype Niger Ghana ecotype. Moreover, the width of the Elytron (Lae) discriminate ecotype Ghana of the ecotype Guinea Conakry. Between the Ghana ecotype and the ecotype Senegal are variables, the length of the pronotum (Lop) and the width of the wing (Laa) that differentiate them. Ghana and Cameroon ecotypes are variables, the length of the antenna (Lan), the length of the pronotum (Lop), third (Lf3) femur length and the thickness of the pygidium (Epy) that distinguish them (table 3). Regarding low discrimination of the Côte d'Ivoire ecotype and the ecotypes of the Niger, Senegal, and Cameroon, it is the length of the pronotum (Lop), which is at the origin.

At the level of the second axis, the Cameroon ecotype differs from the Niger ecotype by the length of the Tarsus (Lt3), the thickness of the pygidium (Epy). Between the Cameroon ecotype and the Guinea Conakry, the variable ecotype, the length of the pronotum which allows low discrimination. This same variable (Lop), in addition to the length of the rostrum (Lr), the length of the tibia (LT3) allowed the distinction of the Cameroon ecotype and the ecotype RCA (table 3).

Transformed measurements:-

Choice of the number of axes to retain after data transformation:-

After processing the data, the number of axes retained with the criterion of the elbow is the same as before the conversion (Figure 4).

Contribution of the variables with their transformed measurements:-

The discriminant factorial analysis revealed that after transformation of the measurements, the first factorial axis has lost 12.87% of its power of inertia. However the power of the second factorial axis inertia rose 2.67%. What makes the power of inertia of the first two axes is equal 36.81%. The highest quality of representation is always obtained by these first two axes. On the first factorial axis, the contribution of some variable is less than what it was before the conversion. This is the case of the length of the tibia (F1 = 5.81), the width of the wing (F1 = 4.49), the length of the femur 3 (F1 = 4.31), the length of the pronotum (F1 = 4.14), the width of the rostrum (F1 = 2.37), the length of the antenna (F1 = 1.36), the length of the pygidium (F1 = 1.25). However the contribution of the length of the coxa 3 on this axis has largely increased, she went from F1 = 0.008 to F1 = 18.5. The variables having the lowest contributions are: the length of the Tarsus (F1 = 0.75), the thickness of the pygidium (F1 = 0.17), the length of the first abdominal sternite (F1 = 0.08). The variables that contribute the most to the construction of the first axis are the length of the coxa 3 (F1 = 18.5), the length of the wing (F1 = 17), the length of the Elytron (F1 = 12.8), the length of the rostrum (F1 = 12.7), the pronotum (F1 = 8.07) width and the width of the Elytron (F1 = 6.21) (figure 16). Following the second factorial axis, the contribution of certain variable has declined compared to what it was before transformation. These variables are the length of the first sternite abdominal (F2 = 9.9), the length of the femur 3 (F2 = 5.97), the width of the pronotum (F2 = 3.94), the length of the Tarsus 3 (F2 = 3.52). By against the contribution of variables such as the length of the pronotum (F2 = 24.4), the width of the rostrum (F2 = 20.3) and the width of the wing (F2 = 12.5) increased considerably. The contribution of the pronotum length went from 14 to F2 = 24.4 = F2, that of the width of the rostrum of F2 = 10.7 to F2 = 20.3 and that of the width of the wing of F2 = 6.88 at F2 = 12.5. On this axis variables that have the lowest contributions are: the length of the pygidium (F2 = 2.61), the length of the Elytron (F2 = 1.77), the width of the Elytron (F2 = 0.32), the length of the rostrum (F2 = 0.20), the length of the tibia (F2 = 0.09), the length of the coxa 3 (F2 = 0.05) and the length of the wing (F2 = 0.002). The variables that contribute the most to the construction of the second axis are the length of the pronotum (F2 = 24.4), the width of the rostrum (F2 = 20.3), the width of the wing (F2 = 12.5), the length of the first sternite abdominal (F2 = 9.9), the width of the antenna (F2 = 7.6), thickness of the pygidium (F2 = 6.9), the length of the femur 3 (F2 = 5.97). The elimination of the effect size is materialized by the dispersion of variables involved and on the other of the two axes (figure 5).

Discrimination of populations with the transformed measurements of variables based on the ecotypes:-

The decrease of the discriminating power of variables following the first factorial axis (Dim 1) enabled on the one hand the rapprochement of the barycenter of the ecotype Mali from Guinea Conakry, Niger and Cameroon and the other reconciliation of the ecotype of the ecotypes of Ivory Coast Ghana, Senegal and the RCA. Thus, on the first axis, the ecotypes of Ghana, Ivory Coast, Senegal and the RCA will discriminate ecotypes of Cameroon, Mali, Guinea Conakry and Niger. These last two are discriminated against following the second factorial axis of the ecotypes of Cameroon and Mali. Along the same axis, Senegal and RCA to discriminate against Ghana and Côte d'Ivoire (Figure 6).

Variables to the discrimination of the ecotypes after transformation:-

On the first factorial axis, the discrimination of the Ghana and Mali ecotypes is due by the length of the wing (Loa). Between the Ghana ecotype and the ecotype Guinea Conakry, is the length of the wing, the Elytron width and length of the coxa 3 which allow the distinction of these ecotypes. While the Elytron width and length of the rostrum confirmed respectively to differentiate the ecotypes Niger and Senegal versus Ghana. Following the second factorial axis, the length of the pronotum (Lop) discriminates against Ghana and Ivory Coast from Cameroon, Niger and RCA ecotypes ecotypes. Between the ecotype Senegal and Ghana Ivory Coast ecotypes, the length of the pronotum (Lop) and the width of the wing (Laa) who are at the origin of the discrimination. Furthermore, the length of the antenna, the length of the pronotum and the length of the pygidium distinguish the ecotype Ghana of the Mali ecotype on this axis. And between the ecotype of Côte d'Ivoire and that of Mali, the variables, the length of the pronotum (Lop) and the length of the pygidium (Lpy), allow to differentiate them (table 4).

To better determine, discrimination between ecotypes, the variables that contribute most to the discrimination (in red) are determined (figure 7A). These are, the length of the rostrum (Lr), the length of the pronotum (Lop), the width of the rostrum (Lar), the length of the wing (Loa), the length of the Elytron (Loe) and the length of the coxa 3 (Lc3). It is with these that discriminant factorial analysis (AFD) (figure 7B). This AFD was to discriminate clearly a group of individuals of the RCA, a group of individuals from Ghana and Ivory Coast, a group made up in majority of individuals from Cameroon, Mali and Niger another made of individuals from Guinea Conakry. However, the Group of individuals of this car a zone of introgression with one of the ivory-Ghana side and on the other with one formed by Cameroon, Mali and the Niger. As the individuals in Senegal, they are dispersed among different groups. Variables that have allowed discrimination against the Group of Guinea Conakry over the RCA Group are the length of the rostrum and the length of the wing. This allows the discrimination of the Group of Guinea Conakry and the ecotype of Ghana. For the group from Cameroon, Mali and the Niger, it is the length of the pronotum (Lop) which differentiates it from others. As for the group formed by the ecotypes Ghana and Ivory Coast, it is characterized by low length of the pronotum (Lop) and the Elytron (Loe). The RCA Group differs from the Group of the side of ivory-Ghana by the length of the pronotum (Lop).

Analyse factorielle des correspondances (AFC) des ecotypes:-

The factorial analysis of correspondences of the transformed data revealed that seven axes describe the insect populations morphometric variability. But that's the plan formed by the first three axes that explain the better the number of group’s morphometric with a total power of inertia to 57.9%. Thus, three groups morphometric are identified: a group made up of the ecotype Senegal, part of individuals of the ecotypes RCA and Ivory Coast, a group composed of Ghana, Niger, Guinea Conakry, ecotypes part of individuals of the ecotypes RCA and Ivory Coast, another group including Cameroon and Mali ecotypes. Following the first factorial axis group Cameroon and Mali clearly separates from the Senegal, RCA and Côte d'Ivoire Group 21.22% of morphometric variability. However, the second axis with 21.18% of morphometric variability allows distinguishing the group formed by ecotypes Ghana, Guinea Conakry, Niger, part of individuals of Ivory Coast, and of the car compared to the group formed by the Senegal ecotype, a part of the people of Côte d'Ivoire and the RCA (figure 8).

Matrix of confusion for the results of cross-validation of the ecotypes:-

The confusion matrix summarizes the reclassifications of individuals to deduce the rate of good and bad ranking. This allows determining the "% correct" which is the ratio of the number of ranked individuals, on the total number of individuals. So, 60% of the individuals of the ecotypes are correctly classified in their population of origin. Guinea Conakry and Mali ecotypes are the most homogeneous populations with respectively 90% and 80% of individuals correctly classified. While the ecotypes in Ivory Coast and Ghana are to be more heterogeneous populations with respectively 20% and 40% of individuals well classified (table 5).

Hierarchical ascending classification depending of the ecotypes:-

The purpose of the hierarchical ascending classification is to create morphometric groups homogeneous from the point of view of the variables. The dotted line represents the truncation and allows to better visualizing the similarity between individuals. The dendrogram in figure 10 shows two classes. The first class consists of a single individual from Guinea Conakry. The second class consists of two sub class: a class made up of an individual of Senegal and an individual from Cameroon, another under class composed of two groups. The first group is formed largely of individuals from Ghana (9), Côte d'Ivoire (8), Niger (6), of a few individuals of Senegal (2), of Guinea Conakry (2) and the RCA (1). The second group is subdivided into two subgroups. The first group is composed of individuals from Mali (5), Cameroon (3), of Guinea Conakry (3), Senegal (2), Côte d'Ivoire (2), of the RCA (1) and Ghana (1). The second group consists of individuals of the RCA (8), Cameroon (6), Mali (5), Senegal (5), and Guinea Conakry (4). After ascending hierarchical classification, the ecotype of Senegal seems to be the most varied because it is present in the various groupings (figure 9).

Structure of the ecotypes morphometric:-

Considering all populations defined by ecotypes, results of the likelihood approach and that of Evanno indicate that the number of morphometric group is obtained for K = 3 (figure 10) Based on the affinity of the individuals of each population variables, three morphometric groups are identified. These groups are characterized by three colors (red, green and blue). The first group of morphometric (red) is composed of individuals of the ecotypes of Senegal (60%), RCA (50%), Côte d'Ivoire (40%), Mali (20%), Niger (20%) and Cameroon (10%). The second group (green) is composed of individuals of the ecotypes of Cameroon (70%), Côte d'Ivoire (60%), Niger (50%), Ghana (50%), Mali (40%), of Guinea Conakry (40%), RCA (30%) and Senegal (20%). The third (blue) group is made up of individuals of the ecotypes of Guinea Conakry (60%), Mali (40%), Niger (30%), Ghana (30%), RCA (20%), Cameroon (20%), and Senegal (20%) (Figure 11).

Discussion and conclusion:-

Discussion:-

According to the criterion of the elbow, two axes are selected for the raw measurements and the transformed data. These two axes explain 47.01% of the raw measurements morphometric randomness and 36.81 percent that of the transformed measurements. This decrease of power of inertia of the two axes between the raw data and the transformed data is due by the elimination of the size effect.

With the raw measurements, following the two axes, for all of the 16 variables used, some ecotypes present similarities between them and the dissimilarities in relation to others. This is the case between the ecotypes Cameroon and Mali, those of the Ghana - Ivory Coast, between the ecotypes Senegal and RCA and those of the Guinea Conakry - Niger. This resemblance and this dissimilarity are especially sharp with the transformed measurements of 16 variables. Among these transformed measurements of 16 variables, six of them to distinguish best ecotypes. It's the length of the rostrum (Lr), the width of the rostrum (Lar), the length of the pronotum (Lop), the length of the wing (Loa), the length of the Elytron (Loe) and the length of the coxa 3 (Lc3). These six variables actually showed a resemblance between the ecotypes Cameroon, Mali and Niger; a scattering of individuals of the ecotype Senegal within the different ecotypes. So by taking, as each variable after transformation, we can say that size equals, Cameroon and Mali ecotypes have a longer rostrum (1,59 mm) and a longer credit (1.44 mm in the Cameroon, 1.42 mm at the Mali ecotype ecotype). The ecotype Mali also has the longest wings (3. 63 mm). The ecotype Niger has the longer elytra (1.91 mm). The longest coxa 3 met among the ecotypes Ghana and RCA (0.34 mm), followed by Niger, Senegal (0.33 mm) ecotypes, Cameroun, Côte d'Ivoire (0.32 mm) ecotypes and finally the Guinea Conakry, Mali (0.31 mm) ecotypes. The larger widths of the rostrum are met in the breasts of the ecotypes Ghana and Ivory Coast.

However, encountered similarities can be seen between geographically remote ecotypes and not having the same conditions agro-ecological and climate except for the case between the Ivory Coast and Ghana. The geographic distances between ecotypes seem not to be decisive in what concerned the similarities, as in the case of the identification population Sudano-Sahelian *Caryedon serratus* morphometric study (Sembène and Delobel, 1996). Indeed, morphologically similar Cameroon and Mali ecotypes are geographically remote 2104.07 km (as the crow flies). On the other hand, the Senegalese ecotype and that of Guinea Conakry geographically close (557.92 km bird's-eye) [1] are morphologically distinct. One might think that the similarities and the differences are linked to climatic and agro-ecological conditions, or the geographical distance of the ecotypes.

With the factorial correspondence analysis (AFC) of the ecotypes, for a power of inertia of 57.9%, three morphometric groups are identified. But nevertheless, the AFC retains certain gathering of AFD. It is the trained group of individuals of the Cameroon and Mali ecotypes. Group composed of individuals of the ecotypes Ghana, Ivory Coast, Niger, Guinea Conakry, and RCA and the group consisting of individuals from Senegal, the RCA and the Ivory Coast.

The analysis of the results of cross-validation of the ecotypes confusion matrix showed that 60% of individuals are properly classified. Individuals of the ecotypes of Guinea Conakry and Mali accordinging to be the most homogeneous populations and those of Ghana and Ivory Coast more heterogeneous. These could be explained that Ghana and Ivory Coast are corn-exporting countries while Guinea Conakry and Mali are marked by a large import of this cereal (CILSS, 2013).

The study of the hierarchical ascending classification of ecotypes which aims to visualize similarities between individuals and to identify morphometric groups indicated a similarity between individuals of different ecotypes. However, an individual of the ecotype Guinea Conakry has a particular morphology compared to all of the individuals in the sample. The similarities found between some individuals are only confirmed the similarities that have been identified between some ecotypes. Such is the case between the Ivory Coast and Ghana ecotypes which are collected in the Group 1; between Cameroon and Mali in Group 2 ecotypes.

The results of the method of reality and that of ecotypes Evanno revealed depending on the affinity of the variables of each population, three groups for the focused all morphometric. The first 60% of the individuals of the Senegal ecotype morphometric group is marked by the absence of individuals from Guinea Conakry. When the second group morphometric, it is characterized by a representation of the individuals of the ecotypes with the majority 70% of the people of Cameroon. With respect to the third group, he identifies himself by the absence of individuals from Ivory Coast.

Conclusion:-

The study of *Sitophilus zeamais* morphometric characterization which aims to determine groups based on the ecotypes morphometric, found morphometric between some of these groups.

However the morphometric groups are identified between geographically remote ecotypes, so geographical distances, or agro-ecological and climatic conditions are not related to morphometric groups.

A characterization morphometric of *Sitophilus zeamais* depending on the different types of corn in these countries is therefore necessary to see whether these various morphometric groups are related to the organoleptic composition of the types of corn sampled.

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