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Morphological characterization and the significance of sexual differences in size among Lipochromic Mosaic Canary bird raised in the Wilaya of Tlemcen Northwest of Algeria

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Abstract

The lipochromic mosaic canary is a cage bird breed present with different coat colors, red, and yellow, this breed presents a significant sexual dichromatism. Dichromatism in lipochromic mosaic canaries is explained by differential carotenoid degradation in the integument, rather than sex-specific variation in physiological functions such as pigment uptake or transport. Males have an intense color compared to females and especially at the shoulders and head. We studied sexual size dimorphism (SSD) because this study aimed to investigate whether gender has an impact on thirteen body measurements which are (Head Length, Head Width, Distance Between the Eyes, Beak Length, Beak Width, Chest Circumference, Body Length, Body Width, Wing Length, Sternum Length, Upper Tarsus Length, Lower Tarsus Length, and Tail Length) in 40 native lipochromic mosaic canaries (19 males and 21 females) raised in the Wilaya of Tlemcen Northwest of Algeria. The results showed that there were differences between genders for three characters that are CC (Chest Circumference), BL (Body Length), and WL (Wing Length). Males had more developed measurable traits than females.

Keywords: Body measurements, Lipochromic mosaic canary, Sexual size dimorphism (SSD).

ملخص

الكناري الفيسفسائي ذو اللون الشحمي هو سلالة من سلالات طيور القفص تتواجد بألوان معطف مختلفة، الأحمر والأصفر، ويمثل هذا الصنف ازدواجًا لونيًا جنسيًا كبيرًا. يتم تفسير ثنائية اللون في طيور الكناري الفيسفسائية ذات اللون الشحمي من خلال تحلل الكاروتين في الغلاف، بدلاً من الاختلاف الخاص بالجنس في الوظائف الفسيولوجية مثل امتصاص الصباغ أو النقل. الذكور لديهم لون كثيف مقارنة بالإناث وخاصة عند الكتفين والرأس. درسنا ازدواج الشكل والحجم بالجنس (SSD) لأن هذه الدراسة تهدف إلى معرفة ما إذا كان للجنس تأثير على ثلاثة عشر قياسًا للجسم وهي (طول الرأس، عرض الرأس، المسافة بين العينين، طول المنقار، عرض المنقار، محيط الصدر، طول الجسم، عرض الجسم، طول الجناح، طول القص، طول الرسغ العلوي، طول الرسغ السفلي وطول الذيل) على 40 طائر كناري فسيفسائي ذو اللون الشحمي الأصلي (19 ذكرًا و21 أنثى) تم تربيتها في ولاية تلمسان شمال غرب الجزائر. أظهرت النتائج وجود اختلافات بين الجنسين على ثلاثة أحرف هي CC (محيط الصدر) وBL (طول الجسم) وWL (طول الجناح). كان لدى الذكور قياسات جسمية أكثر تطوراً من الإناث.

الكلمات المفتاحية: قياسات الجسم، الكناري الفيسفسائي الشحمي، ازدواج الشكل والحجم بالجنس (SSD).

Introduction

Canary (*Serinus canarius*) is probably the most raised in Algeria with the goldfinch according to the testimony of many amateur and professional breeders.

The Spanish sailors certainly introduced this species of birds to Europe around the second decade of the 15th century, because this species derives its wild origin from the Spanish Canary Islands. Cage canaries are the domestic form of the wild canary. (Yenilmez , 2019).

There are three types of canaries, singing canaries like Spanish Timbrado and the Malinois, Form canaries like the Fiorino and the Belgian hunchback, and finally color canaries like the Lipochrome Mosaic. (Pomarède, 1983; Desbonnet, 1994; Gelly, 1999).

The colors of bird plumage are often brighter and more pronounced in males than in females. We speak of "sexual dichromatism". For Darwin, this difference was explained by the action of the females who, for generations, had chosen to mate with the males sporting the most vivid adornments. (Darwin, 1859).

In canaries, breeders can differentiate between males and females according to singing, because males sing and females do not. Two categories are to be considered: canaries with plain plumage without drawing: *lipochrome* with a red, yellow or white background and canaries with drawing or *melanins*. (Gelly, 1999). However, in lipochrome mosaic canary, breeders refer to the coloration for differentiation between genders. In (Type 2) or male type, unlike females (Type 1), the color is more intense in several parts of the body, and the presence of the full-face mask well defined, surrounding the bill and stopping just behind the eyes. In females, the mask is not well defined. (Glémet, 2017).

The BCO2 gene is the main gene responsible for dichromatisme in lipochromic mosaic canaries, researchers have shown that the production of BCO2 proteins was inversely proportional to the amount of pigments present in the feathers of the lipochromic mosaic canary; the protein is highly concentrated in the white feathers, and little present in yellow and red feathers. At the individual level, the less colorful plumage of females comes from an increased production of BCO2 proteins, preventing the accumulation of pigment and therefore the coloring of the feathers. (Gazda *et al.*, 2020).

Some breeders use another technic for differentiate between canary genders, they refer to the position of the eye in relation to the tip of the beak, the eyes of the females are higher than the male (Figure 1). **(**Yenilmez 2019).

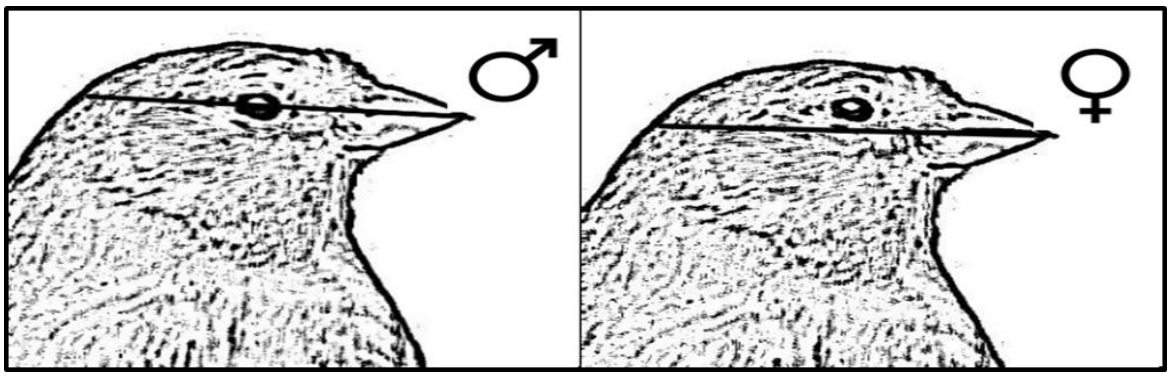


Figure 1. Difference between the position of the eyes among Males and Females canaries. (Akrom *et al.*, 2020).

Therefore, the purpose of this study is to investigate if the body measurement of local lipochromic mosaic canaries raised in Tlemcen have a clear effect on gender identification.

Materials and Methods.

Study area

The Wilaya of Tlemcen occupies an important place in Algeria. It is located on the northwest coast of the country and has 120 kilometers of seaside with an area of 9,017.69 square kilometers. This Wilaya is border by Mediterranean in the north, the Wilaya of Ain Temouchent in the east, the Wilaya of Sidi Bel Abbes in the southeast, the Wilaya of Naama in the south, and finally Morocco in the west (Figure 2). The city of Tlemcen (a principal town on the Wilaya of Tlemcen) has a Mediterranean climate. In winter, the temperature can drop below 0 ° C, and in summer, it can reach 45 °C.

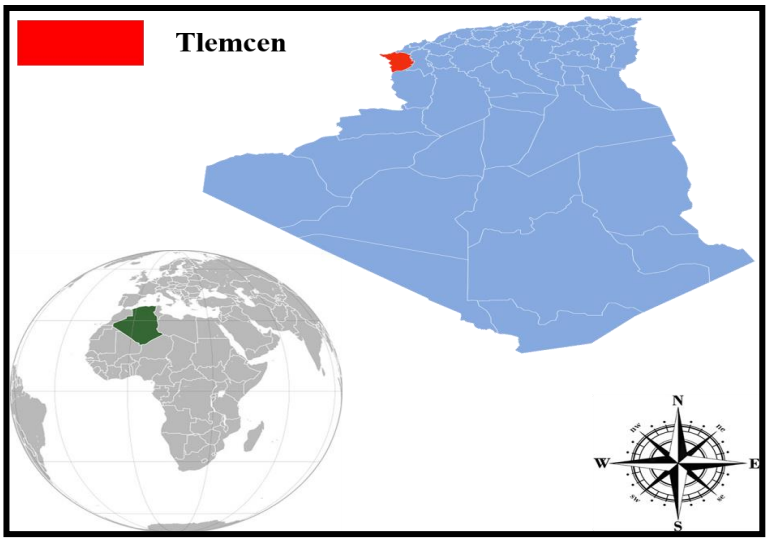


Figure 2. Representation of the studied Area.

Choice of animals:

Our work was based on the study of the morphological traits of forty unrelated lipochromic mosaic canaries (Figure 3) (19 males and 21 females); we excluded from our study all individuals who had a family link, all canaries were adults, between two and three years old, purebreds, raised in the same conditions and under a same diet too. We made sure that all the individuals chosen and studied were in perfect health and showed no signs of any disease. The chosen individuals were neither in mating nor in laying period. The table 1 lists individuals by genders.

Table 1: Distribution of the study sample set by gender.

Area	Males	Females	Total
Tlemcen	19	21	**40**

Figure 3. Male individual Type 2 (Left) and Female individual Type 1 (Right) (original photos).

Morphometric variables

Thirteen quantitative traits have been chosen in our work as shown in the Table 2.

Table 2: Morphometric traits studied in the considered canary birds.

Abbreviation	Measurements	Details
HL	Head Length	Distance between the base of the beak and the back extremity of the head
HW	Head Width	The largest width of the head
DBE	Distance Between the Eyes	The smallest distance between the eyes
BKL	Beak Length	Distance between the tip and the base of the Beak
BKW	Beak Width	The largest width of the beak
CC	Chest Circumference	Circumference taken from withers at up and the breastbone below
BL	Body Length	Distance between the tip of the head and the tip of the tail
BW	Body Width	The largest width of the body
WL	Wing Length	Distance between the bend of the wing to the tip of the longest primary feathers
SL	Sternum Length	Distance between the two ends of the bone
UTL	Upper Tarsus Length	Distance between the inner bend of the tibiotarsal articulation to the base of the toes (up)
LTL	Lower Tarsus Length	Distance between the inner bend of the tibiotarsal articulation to the base of the toes (Low)
TL	Tail Length	Distance between the base of the tail to the tip of the longest feathers

The measurements points used in our study are shown in (Figure 4), the method used has been applied to different domestic animals and birds.

A caliper has been used to measure all quantitative traits except the chest circumference (CC) (Figure 5). This latter trait has been measured by a tape measure. This work has been carried out during the evening depending on the availability of the breeders and our assistant who knew how to hold individuals on whom we had taken measurements without endangering them.

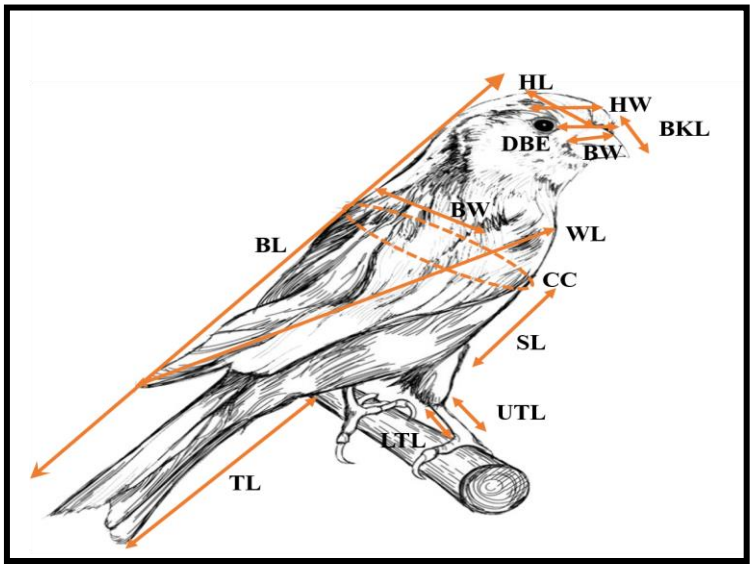


Figure 4. Quantitative traits and reference points measurements in the concidered birds.

Figure 5. Instruments used (a caliper and a type measure).

Statistical analysis

Data were analyzed using IBM SPSS Statistics software (Version.21.0). Descriptive analysis of body measurements in the studied population were determined after checking the distribution of our variables. The impact of sex on body measurements was determined using the t-test. For the investigation on the correlation between measurements pairs, we used Pearson's matrix correlation, a Principal Components Analysis (PCA) was performed in order to identify clusters of animals with similar body measurements and the criteria of the distribution of the individuals. A Hierarchical Ascendant Classification (HAC) was also used to obtain the optimal number of groups in the considered canaries sample set. Finally, we calculated the Shannon's index of morphological diversity using Excel software for Windows (Version.2016), Shannon Index is defined and given by the following function:

$$H' = -\sum_{i=1}^{s} pi * ln(pi)$$

Where ***pi*** is the proportion of total sample present in the interval or the group ***i***, which means, divide number of individuals of interval ***i*** by total number of samples. ***S*** is the total number of groups of each trait, in this study ***S*** was limited to four for each trait using the following partition: [Minimum; Q1 [, [Q1; Q2 [, [Q2; Q3 [, and [Q3; Maximum], where Q1, Q2, and Q3 represent the first, the second, and the third quartile respectively. ***H.max*** = ***ln(S)*** = Maximum diversity possible, and finally ***E*** = Evenness or Pielou Index = ***H'/Hmax***, which inform about equal distribution or equitability.

In other words, we used the ecological Shannon diversity index to estimate the morphological diversity for each trait among the studied population.

Results and discussion

Minima, maxima, means, standard error, standard deviation, variance and the coefficient of variation are summarized in the Table 3. According to the results in Table 3, especially the coefficient of variation, although all variables have the same measurement unit, we can infer that for BKW, CV this coefficient is equal to 15%, but for DBE, BKL and BW, CV this coefficient is equal to 14%. The distribution of the data near the mean is greater than the distribution of other variables, especially the distribution of CC, TL, and BL, which are equal to 7% and 5%, respectively. In other words, we can deduce that the distribution of our sample is homogenous because for each trait the SD value is less than the half of the mean value (SD < 0.5 * Mean).

Related to the t-test results (Table 4) there were no significant differences between males and females' canaries for the traits HL, HW, DBE, BKL, BKW, BW, SL, UTL, LTL and TL. However, there was a significant difference for both CC and WL, and finally a high difference for BL.

As scientists have shown, in higher vertebrates, including some reptiles, especially birds and mammals, males are usually the larger of the two sexes, which is different from many spiders, insects, fish and some amphibians where females are larger and heavier-bodies than the males. We can talk there about reverse sexual dimorphism (RSD). According to some scientists, these differences may be due to the size difference between egg and sperm cells, because the first one is large, full of yolk, nutritious and inactive, while the second is small, active and no stockpiled food. Therefore, they believe that this basic cell difference is often reflected in the size of the adult animal itself (D. Amadon, 1959).

Table 3: Descriptive analysis of body measurements in the studied population.

Quantitative Traits (mm)	Min	Max	Mean	SE	SD	Variance	CV
HL	14.00	24.00	19.68	0.35	2.19	4.79	0.11
HW	11.00	22.00	16.40	0.31	1.96	3.84	0.12
DBE	7.00	16.00	12.53	0.28	1.80	3.23	0.14
BKL	7.00	14.00	9.98	0.22	1.39	1.92	0.14
BKW	4.00	8.00	6.55	0.16	1.01	1.02	0.15
CC	79.00	104.00	92.15	0.96	6.07	36.85	0.07
BL	134.00	164.00	148.88	1.24	7.81	61.04	0.05
BW	24.00	54.00	40.88	0.89	5.65	31.91	0.14
WL	63.00	93.00	80.15	0.95	5.99	35.82	0.07
SL	29.00	53.00	41.90	0.70	4.43	19.63	0.11
UTL	13.00	22.00	17.10	0.29	1.84	3.37	0.11
LTL	17.00	24.00	19.95	0.26	1.63	2.66	0.08
TL	54.00	75.00	65.40	0.68	4.28	18.35	0.07

(SE) Standard Error; (SD) Standard Deviation; (CV) Coefficient of Variation.

In some bird species, there is a reversed sexual dimorphism (RSD), such as *Falco naumanni.* (O. Ganbold *et al., 2019*). In *Melopsittacus undulates,* the results of the t-test revealed no significant differences between males and females, but the differences between genders were only on the phenotypic characters. (Ibnu Baehaqi *et al., 2018*).

Table 4. The impact of sex on body measurements

Gender	Males	Females	Significance
N	**19**	**21**	
HL	20.21±0.41	19.20±0.53	ns
HW	17.00±0.48	15.86±0.37	ns
DBE	12.53±0.47	12.52±0.35	ns
BKL	9.84±0.39	10.10±0.23	ns
BKW	6.53±0.26	6.60±0.20	ns
CC	94.10±1.06	90.38±1.48	*
BL	153.00±1.61	145.14±1.45	***
BW	42.00±1.36	39.86±1.17	ns
WL	82.16±1.22	78.33±1.33	*
SL	41.53±0.85	42.24±1.11	ns
UTL	16.74±0.37	17.43±0.44	ns
LTL	19.79±0.29	20.10±0.42	ns
TL	66.68±0.90	64.24±0.95	ns

: significant ($p<0.05$); *: highly significant ($p<0.001$); ns: no significant ($p>0.05$).*

The study on the White-crested Elaenia showed a significant difference between males and females for the characters wing length (WL) and tail length (TL), where the males shown a size more important than females. (Víctor cueto *et al., 2015*).

In quails raised in Algeria, the differences between males and females were for the tail length (TL), where males yielded than females, but for both abdomen length and chest width females yielded than males. (Kadraoui *et al., 2020*).

We can also refer to the study on Spanish goldfinches whose was based on the effect of life in captivity and the wild life of this species, but also on the effect of sex on some body measurements of which we can cite the significant difference between the two genders for the length of the wings, where the males had more developed wings than those of the females. (Domíngue *et al., 2010*).

According to the results of our study and those of the studies cited before, we can notice that the Wings Length (WL) is the most common trait that varies between the genders of different species of birds, and is more developed in males than in females.

According to our research results and the previously cited research results, we can notice that wing length (WL) is the most common feature, which varies between the sexes for different birds' species with noticing that males have more developed ones than females. As cited in the beginning, this phenomenon is common in many animal families and species; we can cite like an example of mammals' species the impact of sex in Algerian Sighthounds raised in the Wilaya of Tlemcen where the majority of males' traits were more developed than those of females. (Haddam *et al., 2021*).

Table 5: Pearson's Correlation matrix Erreur ! Liaison incorrecte.We can finally notice that our work confirms one of the most known assertion of Charles Robert Darwin the designer of the Evolution Theory, where most birds exhibit male-biased sexual size dimorphism (SSD), when he declared that "*The males of many birds are larger than the females, and this no doubt is the result of the advantage gained by the larger and stronger males over their rivals during many generations*". **(**Tamas Szekely *et al., 2007*).

The Pearson's correlation matrix (Table 5) shows that for both genders, the variables are positively correlated for some ones and negatively for others; HL has a significant positive correlation with both BKW and BW.

HW has a very significant positive correlation with DBE, BKW, and BW, a significant positive correlation with BL, and finally a significant negative correlation with SL.

DBE has a very significant positive correlation with BKW and BW, and a significant positive correlation with BKL.

BKL has significant negative correlation with SL, and BKW has a very significant positive correlation with BW, and a significant negative correlation with SL.

Both CC and BL have respectively a very significant positive correlation and a significant positive correlation with TL.

BW has a very significant negative correlation with SL, and a significant negative correlation with both UTL and LTL.

WL and SL are positively correlated with a very significant degree, and finally UTL and LTL are positively correlated with a very significant degree.

From our interpretations, we can say that within our population all individuals who have a larger head will also have a wider beak, a greater distance between the eyes and a greater body width as well.

The results of the principal component analysis (PCA) (Figure 6) on body measurements showed that the axes 1 and 2 (Dim 1 and Dim 2) represented 44.38 % of the total inertia.

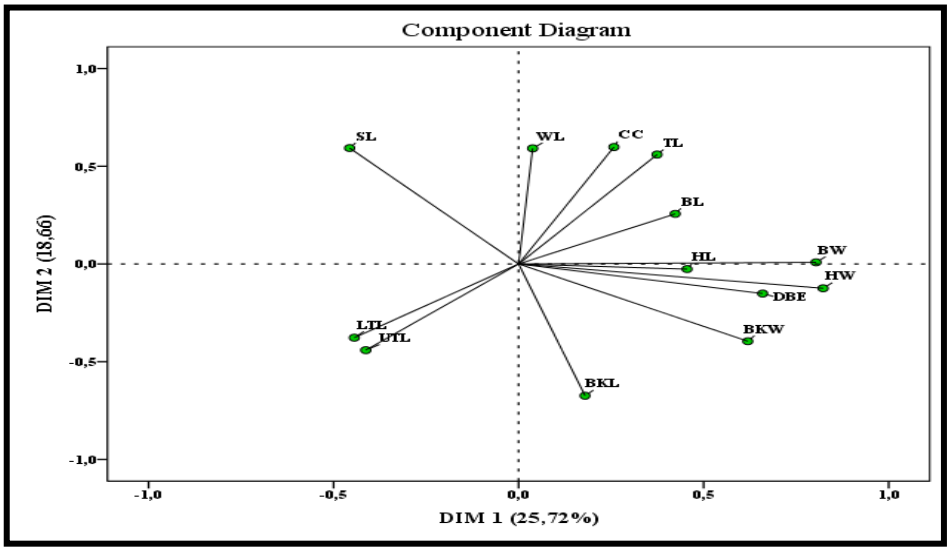


Figure 6. PCA of body measurements of the considered bird samples.

The graph shows the formation of five groups, the first one contains WL, CC, TL and BL, the second contains HL, BW, HW, DBE and BKW, this group contains many head characters, the third contains only BKL, the fourth contains only Tarsus's characters, and finally the fifth group contains only SL.

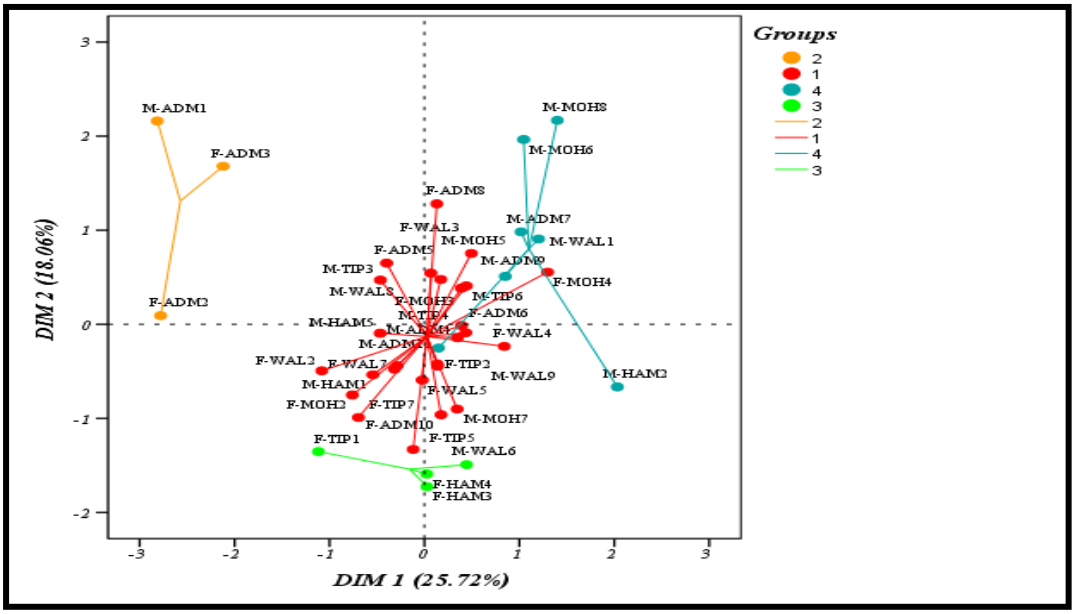
HL, HW, DBE, BKW, BL, BW, and LTL represent a great part of the inertia of DIM 1. However, BKL, CC, WL, SL, UTL, and TL represent a great part of the inertia of DIM 2. The values representation of the variables for each axis are given in the Table 6.

To represent the relation between individuals studied using the principal component analysis (PCA), we used the prefix "M" to indicate males and the prefix "F" to indicate females (Figure 7).

The graphical representation of individuals using the PCA in Figure 7 shows that individuals were grouped according to their body measurements similarities and not to their sex. We can also notice that some females have a developed body measurement just like males, while some males present a less developed body measurement than the average. The group that contains only males' canaries is the group 4. All the other ones (group 1, 2 and 3) contain individuals of both sexes.

Table 6: PCA components matrix, the values representation of the variables on each axis.**Erreur ! Liaison incorrecte.Figure 7.** Individuals' representation of the considered canaries samples using PCA.

According to both Figure 8, Table 7, and Figure 7, we can suggest the existence of four different groups with a different composition. The first group (Group 1) is the largest one with 26 mixed individuals. The second one is Group 4 with seven males only. The third one is Group 3 with 4 individuals, and finally the fourth one is Group 2 with 3 individuals. We can also notice that the individuals falling in Group 4 yielded higher results for eight considered traits, which are (HL, HW, DBE, CC, BL, BW, WL, and TL). Although the test used before (Table 5) showed a significant difference between the two genders for three traits. Our present classification reveals that individuals of different genders can be found within the same group.



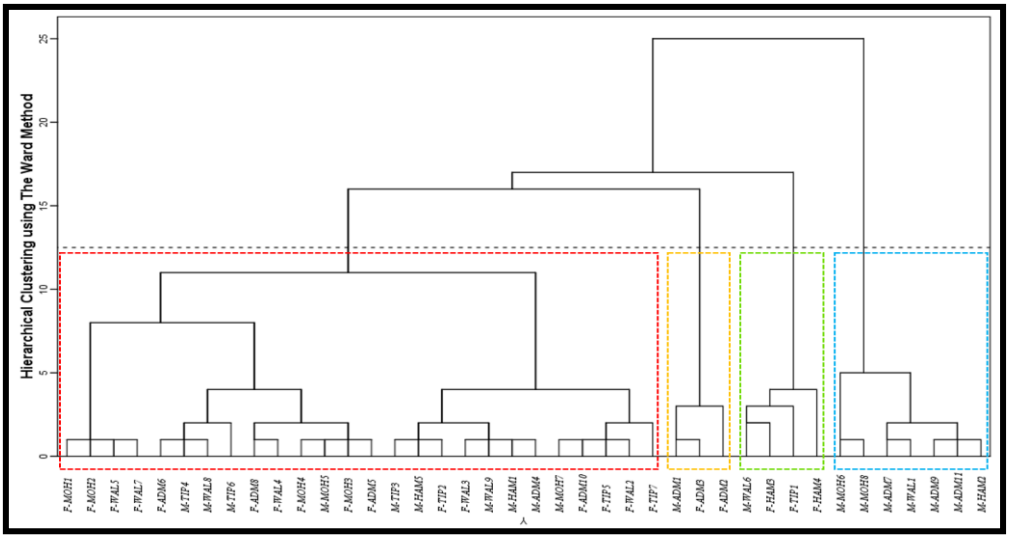


Figure 8. Hierarchical tree of Lipochromic Mosaic Canary using the Ward Method.

Table 7: Variations between groups identified by Hierarchical classification.

Quantitative Traits (mm)	Group 1	Group 2	Group 3	Group 4
N Total	**26**	**3**	**4**	**7**
Gender	Males = 10 Females = 16	Males = 1 Females = 2	Males = 1 Females = 3	Males = 7 Females = 0
HL	19.8 ± 0.4	17.3 ± 0.9	18.8 ± 0.9	20.9 ± 0.6
HW	16.4 ± 0.3	12.3 ± 0.9	16.3 ±0.8	18.1 ± 0.7
DBE	12.7 ± 0.3	9.7 ±1.3	11.8 ± 1.3	13.6 ± 0.5
BKL	10.0 ± 0.2	8.7 ± 1.2	10.8 ± 0.5	9.9 ± 0.9
BKW	6.8 ± 0.2	4.3 ± 0.3	6.8 ± 0.3	6.6 ± 0.4
CC	92.0 ± 1.1	93.7 ± 2.6	86.3 ± 3.8	95.3 ± 1.9
BL	147.1 ± 1.2	146.0 ± 2.9	142.0 ± 2.9	160.7 ± 1.2
BW	41.2 ± 0.5	25.7 ± 1.2	41.3 ± 1.8	46.0 ± 2.0
WL	81.3 ± 0.8	82.0 ± 3.2	66.8 ± 2.6	82.6 ± 1.1
SL	41.5 ± 0.5	52.3 ± 0.7	35.5 ± 2.3	42.6 ± 1.2
UTL	17.3 ± 0.3	18.3 ± 1.9	16.8 ± 0.6	16.0 ± 0.8
LTL	20.0 ± 0.3	21.0 ± 1.7	19.8 ± 0.9	19.3 ± 0.5
TL	64.6 ± 0.7	66.0 ± 1.5	61.5 ± 2.6	70.4 ± 0.7

According to the results on Table 8, we notice that for all the studied traits the value of the Shannon diversity index (SDI) is high which means that there is a great diversity within the studied individua ls. This value reaches the maximum (1.38) for the traits CC, WL, and TL. For HL, the value of SDI was 1.14 that represents the smallest ones. This diversity can be explained by the absence of selection since these animals are breeding in good environmental conditions by opposition of the natural conditions. The overall mean of SDI was 1.31; we can therefore deduce that our studied population has a great diversity.

The equal distribution or the equitability of our SDI is represented by the Pielou index, the most equitable distribution are those of TL, WL, CC, and BL with a maximum value for TL (1.00), and 0.99 for all WL, CC, and BL. Since this index varies from 0 to 1, so when it tends towards 0, this means that almost all the numbers or traits values tends to be concentrated on a single class. It tends towards 1 when all the classes have the same abundance. (Barbault, 1981).

Table 8: Shannon diversity index and Pielou index for the considered sample set.

Quantitative Trait	SDI	PI
HL	**1.14**	**0.82**
HW	1.27	0.92
DBE	1.27	0.92
BKL	1.28	0.92
BKW	1.27	0.92
CC	**1.38**	**0.99**
BL	1.37	**0.99**
BW	1.32	0.95
WL	**1.38**	**0.99**
SL	1.36	0.98
UTL	1.32	0.96
LTL	1.30	0.94
TL	**1.38**	**1.00**
Mean	***1.31***	***0.95***

(SDI): *Shannon Diversity Index****; (PI):*** *Pielou Index.*

The equal distribution makes it possible to appreciate the imbalances that the Shannon diversity index cannot detect. The more its value tends to approach 1, the more it reflects a well-balanced settlement. (Legendre and Legendre, 1979).

We can deduce that all the studied traits are well balanced especially TL, WL, BL, and CC because their PI values were 1, 0.99, 0.99, and 0.99 respectively. For the other traits HW, DBE, BKL, BKW, BW, SL, UTL, and LTL the PI value was between (0.92 and 0.98). Finally, for HL the PI value was 0.82 and the smallest one, we can deduce that for this trait the equitability was less than those of the other traits were, but acceptable as being good.

Conclusion

The present study addresses for the first time the significance of sexual dimorphism in cage birds especially in the lipochromic mosaic canary. The overall results of our study reveal that the native lipochromic mosaic canary raised in the Wilaya of Tlemcen shown a SSD for the three characters CC, BL and WL, and no RSD concerning the studied traits.

This study represents the first step in investigating other caged bird species raised in Tlemcen Province and possibly elsewhere in Algeria, as well as other birds that live in the wild, in order to better understand and study the phenomenon of SSD and confirm whether it can change between the two different lifestyles of captive breeding and wild life.

Finally, we can infer that there are many important relationships between gender and body measurements in different studies. These relationships may be due to the influence of gene networks or pleiotropic genes. We can exclude the influence of the environment because all individuals are They were born and raised in the same environment, they all eat the same food, and all the cages they live in have the same size.

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