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REVIEW OF THE TAXONOMIC STATUS OF THE MOST FREQUENT ORTHOPTERA SPECIES (CAELIFERA: ACRIDIDAE)IN THE MIDDLE ATLAS OF MOROCCO

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ABSTRACT

Located between the coast and the desert, the Moroccan Middle Atlas Mountains are strongly affected by these two climatic averages, resulting in very complex and diverse biodiversity patterns in Orthoptera fauna. This instability in locusts (Orthoptera, Acrididae), is mainly due to the ambiguity of definitions for each level of classification above the species level. These changes necessitate a review of the literature on the Moroccan Middle Atlas locust orthopterans. This review focuses on the suborder Caelifera, encountered at five stations in the Middle Atlas, and includes the three families of Acridoîdea, of which the Acrididae is the most diversified. A comparative reading of the various taxa frequently met with and their recent systematic controversies are reviewed herein.

Key words: Middle Atlas, Acrodoîdea, Acrididae, Morocco, mountains, taxonomy, faunistics, morphology, review, checklist, speices diversity

The locusts belonging to the order Orthoptera are diversified, some are polyphagous and feed on several plant species, while others are oligophagous, with diet limited only to a few plants, and finally the monophagous, which have a trophic preference for a specific plant species. Orthoptera is one of the largest insect groups, with > 12,000 species of locusts described worldwide; of these around 500 speceis are causing losses in agricultural and pastoral production (Rouibah, 2018). The greatest number of these species classified as harmful to agriculture are found in the African continent, of which there are > 17 species of Caelifera (Acrididae) in North Africa (Singh and Kumari, 2021). Food production losses due to insect pests are estimated at 20 to 30%, particularly in developing countries (Nwilene et al., 2008). Most locust Orthoptera are polyphagous (Katel et al., 2021), but they may exhibit trophic preferences towards some plant species. The chemical composition in their biotope and the content of nutrients essential to their growth impact these (Wang et al., 2020). In addition to their ability to move, the nature of their mouth parts, the composition of their labrum and antennae in chemoreceptors, as well as their ability to digest the plant (Guerrero et al.).

It is now well established that Orthoptera can be considered a good indicator of ecosystem integrity (Alignan et al., 2018). They represent relevant parameters for assessing the ecological value of natural environments (Kaláb et al., 2020; Sobhi et al., 2013), and richness and seasonal composition of grasshopper communities (Literature shows that several researchers have explored the orthoptereocenoses in several regions of Morocco and the Middle Atlas is one of them. However, several questions remain on the orthopteran fauna in different biotopes, and controversies remain on the importance of the phallic complex as a fundamental character of identification. These can vary considerably within a species (Descamps and Mounassif, 1972). Some taxa of these Orthoptera deserve to be reviewed, and the family Acridoidea, is one such. Many superficially similar genera were found to be totally independent of the time when their external characters were carefully compared. For example, the genera *Acrida* and *Truxalis*, which appear to be morphologically similar, were generally considered to belong to the same family, while the latter belong to distinct subfamilies (Jago, 1966). To fill such gaps, this work would review the descriptive criteria of locust species of the Moroccan Middle Atlas.

An Orthoptera is an exopterygous heterometabolous insect whose metamorphosis is incomplete. It belongs

to the branch of the *Arthropoda*, under the branch of the *Antennates* or *mandibulates*, a class of insects underclass of the *Pterygotes*. The main characteristics of these insects are the mouthparts of the crusher type, the posterior wings strongly criticized, transformed into rigid elytra, the lower wings or membranous still translucent and with distinct venation folded into a fan when resting, the *Orthoptera* belong to the section *Neoptera* and more specifically *Polyneoptera* whose hind legs are longer than the forelegs, hence their adaptations to jump. The morphology of locust species was, since antiquity, the criterion most often used for species identification (Chopard, 1943a; Dirsh, 1956; Jago, 1963; Louveaux et al., 1996). However, other biological parameters have been taken into consideration by some authors, including Chopard (Chopard, 1920), who was the first to introduce the structure of the internal organization, mainly the genitalia, for systematic purposes for certain species of *Orthoptera* and more. Especially in the Pamphagidae. Since then, genitals have been used by a few other authors as additional characters for the differentiation of species and genera expression. Genitals in males were used by Roberts (Roberts, 1941), Uvarov (D and Rançois, 2013; Uvarov, 1943) and Dirsh (Dirsh, 1956) and in females by Slifr (Dirsh, 1957; Slifer, 1958) in the late 1950s.

Other important criteria were introduced into the systematics of *Acridoidea,* such as the stridulatory mechanism. The ability of certain grasshoppers to produce sounds detectable by the human ear had been known since ever, but the relationships between the types of sound-producing mechanisms and the taxonomy were only highlighted around the 1940s. A variety of structures used for stridulation have been described (African and Territory, 1946; Chopard, 1938; Henry, 1942; Kevan and McKeith, 1952; Uvarov, 1942). Such structures exist in the majority of families and subfamilies, while their regular absence in others also seems characteristic. In this case, the basis of the North African *Orthoptera* classification was established in 1943 by Lucien CHOPARD. Since its release, several genera have been revised. New species have been described by several authors who have worked on the African continent (Dirsh, 1961; KEVAN, 1982; Louveaux and ben Halima, 1986; Otte, 1994; Rowell and Hemp, 2017; Vickery, 1987). Indeed, the order of the *Orthoptera*, formerly called *Saltatoria* by Ander (Ander, 1939), is divided into two sub-orders; *Ensifers* or *Locustoidea* of *Handhrsch* and *Caelifera* or *Acridioidea* of *Handhrsch* with the differences schematized in Table 1. However, even somegreat authors (Jakobson, 1904), considered all the superfamilies of Ander as suborders. Whereases, Others (Dirsh, 1961; Uvarov, 1925) omitted the term suborder and used the term superfamily instead.

A. *Ensifers*: The particularity of the insects belonging to this suborder is that they are characterized by the presence of long and thin antennae, composed of more than thirty articles and are morelonger than the body. Except *Gryllotalpidae*. Female genital valves (oviscapte) are well developed and present themselves, like a laying organ, in the shape of a saber, or a tube used to deposit the eggs in the ground or the plants.

B. Caeliferae: The *Acrididae* family is the most representative in a number of Subfamilies and species and presents such homogeneity that it is currently considered to be the only family belonging to the suborder *Caelifères*, hence the word Acridian to designate a locust (Fellaouine and Louveaux, 1993). According to Louveaux and Ben Halima in North Africa, this family includes thirteen subfamilies (Louveaux and ben Halima, 1986). The Caeliferae comprise three superfamilies, namely: *Tetrigoidea, Tridactyloidea*, and *Acridoidea.*

a. Tetrigoidea: Individuals belonging to this superfamily are characterized by the presence of a pronotum prolonged behind with elytra well reduced to small lateral scales. These include individuals of small size and dark color. They live in humid soils where the vegetation is not very dense. They are active during the day and they seem to be very dependent on the ambient temperature. According to Dirsh the epiphallus is absent in *Tetrigoidea,* the pseudosternite, described by Walker (Walker, 1922), cannot be considered homologous to the epiphallus of *Acridoidea* and probably represents a structure of different origin. Unlike the *Acridoidea*, the penis of the *Tetrigoidea*, except the Trigonopterygidae family, is directed towards the anterior end of the body.

Other more recent authors specify that the posterior tarsus is elongated, longer than the apical spurs (Baehr, 1988), while denying the presence of auditory organs involved in stridulation. In individuals belonging to theseSuperfamilies, the eggs are deposited in the form of clusters in the ground, glued to each other, but without a protective envelope of foamy material, as has been observed in several other species of locusts.

b. Tridactyloidea: The *Tridactyloidea* represent the earliest divergent branch of the *Caelifera* (Song et al., 2015). They are characterized by small size, small

head and prognathic or orthognathic shape with a very clear epicranial suture, short antennae, inserted on a small swelling (projection) below and a little outside the eye, the posterior tibia armed exposures in the form of lamellae in place of spines, abdomen terminated by four appendages; the cerci of one or two articles, and prolongations of the paraproctes; ovipositor reduced; arched pronotum. The *Tridactyloidea* include about fifty species described by Duranton and collaborators (Duranton et al., 1982).

c. Acridoidea: The general orthoptological and entomological works report the main changes related to the systematic position of *Acridoidea* during this century in Table 1. Handlirsch (Handlirsch, 1908) divided the order Orthoptera Latreille, 1793 (Saltatoria Latreille, 1817), into two suborders *Locustoidea*, with the families *Locustidae* (*Tettigoniidae*), *Gryllidae*, *Tridactylidae*,*Gryllotalpidae*, and *Acridioidea* with a single family *Acridiidae*. Ander (1939) divided the order *Saltatoria* into the suborder *Ensifera* and *Caelifera*, the former corresponding to Handhrsch's *Locustoidea* and the latter to Handlirsch's *Acridioidea*, except that he transferred the family *Tridactylidae* from the suborder *Caelifera* to superfamily (Ander, 1939). The *Acridoidea* were considered by him as the second superfamily of the suborder. Some authors, however, even more pregnant like Jakobson and Bianchi, considered all Ander superfamilies as suborders(Jacobson and Bianchi, 1904). Other authors have omitted the super order in favor of the superfamily.

Acridoidea are considered a superfamily of the order *Orthoptera*. This superfamily is composed of fourteen families (Duranton, 1982): *Eumastacidae, Proscopidae, Tenaoceridae, Pneumoridae, Xyronotidae, Trigonopterygidae, Lathiceridae, Charilaidae, Pamphagidae, Pyrgomorphidae, Ommexechidae, Lentulidae, Pauliniidae* and *Acrididae*. with more than 10,000 species (Bonnemaison, 1961). More recently (Song and Mariño-Pérez, 2013). in his revision based on the analysis of the phallic complex of males, he reduced the number of families of Acridoidea to 11 families namely: Acrididae, Pamphagidae, Pyrgacrididae, Dericorythidae, Lentulidae, Lathiceridae, Lithidiidae, Ommexechidae, Pamphagodidae, Romaleidae, and Tristiridae(Song and Mariño-Pérez, 2013). This revision suggests new family names. In our synthesis we will retain the nomenclature of Chopard, which constitutes, until now, a fundamental key for the identification of the *orthopterans* of North Africa in general and Morocco in particular (Chopard, 1943a). In North Africa, Louveaux and Ben Halima had reported the presence of four families namely: Charilaidae Pamphagidae, Pyrgomorphidae and Acrididae (Louveaux and ben Halima, 1986). Thus, the present study aims to study the taxonomic position of the Acrididae family of the Moroccan Middle Atlas.

I. Acrididae

According to Dirsh, the acrididae family is divided into the following subfamilies: Hemiacridinae, Romaleinae, Calliptaminae, Euryphyminae, Catantopinae (Cyrtacanthacridinae by some authors), Acridinae (which includes the ancient Oedipodinae as a tribe), Egnatiinae, Eremogryllinae and Truxalinae(Dirsh, 1956). For our study we considered the Oedipodinae as a family. To identify the genera of this family, Chopard focused on the prosternum which has neither tubercle nor groove along the anterior edge. In addition, Bey-bienko and Mitstshenko, suggested the division of the family into two groups. The first with prosternal

Table 1. Status of Acridoidea

Authors	Order	Sub-order	Superfamily
Jakobson et Bianki, 1904	Orthoptera	Acridiodea	-
Handlirsch, 1908	Orthoptera	Acridioidea	-
Chopard, 1920	Orthoptera	Locustodea	-
Schorder, 1925	Saltatoria	Acridiodea	-
Uvarov, 1928	Orthoptera	Acridodea	-
Weber, 1938	Saltatoria	Acridoidea	-
Ander, 1939	Saltatoria	Caelifera	Acridoidea
Chopard, 1949	Orthoptera	Caelifera	Acridoidea
Shvanwitsh, 1949	Orthoptera	-	Acridoidea
Bey-Bienko et Mistshenko, 1951	Orthopthera	Caelifera	Acridoidea
Beier, 1955	Saltatoptera	Caelifera	Acridides
DIRSH, 1961	Orthoptera	Acridoidea	-

appendage and a second without appendage. Thus, the epiphalus of Acrididea without prosternal appendage is composed of distinct lateral plates which are joined by a narrow arched bridge (Bei-Bienko and Mishchenko, 1951). The stridulation mechanism in most sub-families of Acrididae corresponds to the friction between the elytra and the hind legs. In the group of Oedipodinae and Acridinae, The corresponding stridulatory motion is under the governance of a serrated interlayer vein of the elytra vein and a sharp edge on the inner surface of the posterior femur.

i. Oedipodinae subfamily

Some authors, like Chopard, have mentioned the rounded nail that forms the vertex in these insects with the forehead. This author adds some distinctive information, such as the triangular shape of the temporal foveola and an intercalary rib on the elytron allowing stridulation movements by friction at a ridge on the internal face of the posterior femurs (Chopard, 1943b). While, Default and Lecoq were based essentially on the shape of the antennae, which are filiform and the absence of the prosternal tubercle. But the intercalary rib is still persistentfor this description to the stridulatory system serrulate in the males and also most often, in the females. It is an open mesosternal space (Defaut, 1999; Lecoq, 2010).

In the present study, we review the works carried out on the orthopterans of the Middle Atlas and we selected the set of main criteria which allowed the identification of locust species during the last four decades. From these data, we count the elaboration of an identification key of locust species of the Middle Atlas. This will be of great interest to us.

1. *Oedaleus decorus:* This specie is usually marked with a green or testaceous color with dark spots. Bulky, rounded head. Short pronotum with a high median carina. Wings with a black band separating the yellowish or greenish basal zone from the hyaline apical zone (Ryelandt, 2014). Elements of this genus are included by Dirsh in 1975 in the subfamily *Oedipodinae*. On the basal half of the tegmina They have two large brown spots. Based essentially on the morphological characters, Ritchiedescribed certain characters at the level of the pronotum such as the cruciformshape of the pronotum always with the anterior and posterior arms separated; straight, non-converging posterior arms (Jeremy Bark Ritchie B.Sc., 2014).

2. *Acrotylus fischeri* is a large species. It is characterized by elytra with a white spot towards the apical third. At the level of the wings, the Cu and Cu p ribs are parallel and almost contiguous. The wings are tinted bright pink with well-developed apical spots that may merge to form an apical band (Presa, 1979). In the measurements made by Defaut and Puissant in 2014 the antennae are shorter than the pronotum plus the head (Efaut and Uissant, 2014). The rough character of the pronotum is also constantly seen and the angular posterior edge with a protruding median carina. The lateral lobes bear a prominent white patch (Sardet and Defaut, 2004).

3. *Acrotylus insubricus:* The details reported by Chopard focus on the appearance of the head, which is quite conical in subjects of this type, with a triangular vertex shape at the top. It also indicates the rough shape of the pronotum, with a subangular posterior edge. Posterior femora with a blackish internal face bearing three triangular brown spots on it. In this species, the antennae are somewhat thickened at the apex and somewhat longer than the head and pronotum combined. The wings are half bright pink at the basal part keeping the apical half hyaline. The elytra are quite wide with an anterior edge dilated at the base longer than the abdomen (Chopard, 1943b).

Along the same lines, Louveau focuses on The body of this species, which is generally slender than that of Fisheri. By emphasizing two fundamental traits; the slightly domed shape of the median carina in front of the first furrow and the appearance of the tegmina extending beyond the posterior femurs with two brown spots (Louveaux et al., 1996). Likewise, it refers us to the bright pink wings at the base, as Chopard had pointed out. Based on the phallic complex, S. Usmani in 2017 refers in this species to the character of a penis relatively wide and not divided in the middle, anterior edge curved in the middle; ancorae elongated, narrow with curved and pointed extremities, small anterior projection with obtuse apex (Usmani, 2017).According to Default, only the apical first lobe of the wing is stained dark. The prozone of the pronotum is lower and strongly bumpy (Defaut, 1999).

4. *Thalpomena algeriana:* Dirsh and Uvarov 1949. revealed that the wings are very broad, with a strongly convex outer margin and a tiny sinuous intercalary vein at the apex approaching and almost touching the posterior radial vein (Dirsh and Uvarov, 1949) They indicated that the pronotum is devoid of any narrow linear median carina. Short and broad posterior femur. Concerning the phallic complex they described a set of characteristics such as the male's sub-genital plaque which is very short, substantially conical at the apex,

a thin and short ovipositor with curved valves while insisting on the lower valve with an expansion on the outside edge (Dirsh and Uvarov, 1949). Moreover, the morphological characters questioned by Louveau, recall the form of the unrestricted pronotum in the prozone, the fastigium of the summit as broad as long, the fine median keel, raised forward of the first furrow, the black femurs inside with a light spot near the knee, the yellow and black posterior tibias at the apex, and the broad shape of the tegmina is truncated at the apex. According to the molecular tool, Mousi, suggested that species belonging to this genus in North Africa are monophyletic, although they represent morphologically distinct species. Thus, we suggest that the species may simply not be old enough to have accumulated enough mutations (Moussi et al., 2018) especially for taxa for which morphological identification is difficult.

One current limitation of barcoding is the lack of reference sequences for many groups. While many European and North American countries have started their own barcoding initiatives to generate complete local inventories and databases, such efforts are sparse for African, Asian and South American countries, despite their high biodiversity and comparably poorly explored faunas. Therefore, it is important to start local barcoding efforts in such countries. In this study we performed DNA barcoding for the band-winged grasshoppers of the Biskra province in Algeria, a region of high diversity for this taxon. All specimens were identified morphologically and then barcoded. We generated a total of 47 sequences of the COI gene for 22 morphologically identified species of Oedipodinae, many of which were sequenced for the first time. We present the data in a phylogenetic tree, which suggests monophyly for most genera, but rejects it for Sphingonotus and Vosseleriana. Statistical species delimitation worked well for most genera, except those within the Sphingonotini, likely because these have radiated rather recently. Together with data sourced from the literature we used our new data set to generate an updated list of band-winged grasshoppers for the region. Several species are recorded for the region and for the country for the first time. One species appears to be new to science. Furthermore, we found geographic variation within several more widespread species for which data from other countries were present. We consider the new data as an important resource for future faunistic, ecological and biodiversity studies and point out the importance of local (taxon-specific.

5. *Oedipoda fuscocincta:* Chopard indicates it as the close species of *O. coerulescens*. It is distinguished by wings generally of a beautiful yellow, sometimes however greenish, with the arched black band not prolonged in the anterior field towards the base of the wing. The black band extendstowards the base, and reaches the 11th or 12th section of the anal field. This last character is reverified byLouveau while specifying that it does not reach the cubital field, a character which distinguishes him fromthis author of *O. caerulescens*. The latter, by linking some confusions reported by certain very old systematists to the species belonging to this genus, he mentions the presence of a right median keel at the level of the pronotum cut by the typical furrow in the anterior third, a dark blue tibia with a pale ring and a black inner femur with a light brown ring(Louveaux et al., 1996).

6. *Oedipoda coerulescens:* Faithful to its classic way, Chopard describes this species by highlighting the shape of the head and the pronotum which is quite rough and the elytra with three dark, irregular and spotted transverse bands. He also notes the bright blue wing color with a wide black band towards the front edge, much narrower towards the inner edge. It should also be noted that the hind femora in this species are body color with two dark spots and bluish hind tibiae. In contrast, the medial carina of the pronotum of Oedipoda coerulescens is carefully straight at the level of the prozone and barely higher in the metazone. Thus, Louveau caught up with the old systematists on certain characters as meticulous as the shape of the rough occiput, the fascia of the wings reaching the edge of the wing but not exceeding the 10th anal segment (Louveaux Alain, 1986). Some phylogeneticistshave confirmed the presence of a narrow clear line at the posterior edge of the pronotum. This character of genetic or hereditary origin remains poorly explained.

7. *Oedipoda miniata:* This speciesis characterized as Chopard pointed out by the presence of three darker transverse bands at the level of the elytra and wings with a pink base crossed by a narrower black bowin *O. fescosincta*. Kevan surfaced a particularly remarkable character in *O. miniata*, which is the tendency of the spermathecal appendage to become greatly reduced (Kevan et al., 1968). The majority of taxonomists have agreed on a set of morphological characters to identify this species. In addition, Louveau underlines the profile of the median carina of the pronotum, which is projecting and acute at the level of the prozone, the posterior edge of the pronotum at an equally acute angle. The latter also stopped on the shape of the facies at the level of the wings, the latter does not reach the 9th anal rib, and it extends in the cubital field almost

to the base of the wing. Another character which is the pre-apical sinuosity at the upper carina of the posterior femurs can be decisive in distinguishing species within the same genus (Defaut, 2006). Furthermore, the observations mentioned by Unal regarding the pigmentation of certain parts of the body in certain specimens of *O. miniata,* especially at the level of the basal part of the wings, this one is slightly pink-white, instead of the typical dark pink color (Ünal and Unal, 2000). This finding confirms the involvement of certain juvenile hormones in the phenomenon of homochromy (Yerushalmi and Pener, 2002).

ii. Acridinae subfamily

The Acridinae are generally characterized by a quadrangular temporal foveola, elytra rarely presenting an intercalated rib; wings usually transparent. According to Chopard, this subfamily presents the vertex with the forehead and gives the appearance of an acute angle. The stridulatory system is ensured by ridges on the internal face of the posterior femurs (Chopard, 1943a). However, and based on the shape of the *Acridinae* phallic complex. Dirsh predicts that the epiphallus is extremely uniform in the subfamilies Acridinae, Egnatiinae, and Truxalinae, while remarking the difference of this from the other subfamilies of *Acrididae* in that the *ancorae* are articulated with the disc and that lophi are almost invariably lobiform, tending to become unilobed or trilobed (Dirsh, 1956).

1. *Aiolopus strepens:* The body of *Aiolopus strepens* is quite strong and elongated, the profile of the pronotum, a little convex, the elytra brown with some light spots along the anterior edge bluish. According to Chopard the posterior femora of this species are very wide, testaceous on the external face, reddish on the internal face with two black spots, and the posterior tibiae is of purple color with a light spot, followed by a ring black, at the base (Chopard, 1951). Dirsh for his part, aimed at the shape of the wings and the antennae. Thus, it reveals that the tegmen are finely stippled pointed.. Filiform antenna, as long or longer than head and pronotum combined. Fastigium of vertex elongated, angular, slightly concave, with well-developed lateral keels; fastigial foveoli elongated, twice or as long as wide, trapezoidal and shallow; oblique foreheads; frontal crest flat, slightly narrowed at the apex (Dirsh, 1961). Contrary to the description of chopard 1951. Louveau designates *A. strepens* as a polymorphic species in size and color. The shape of the pronotum is almost flat, slightly constricted in the prozone with a well-marked straight median carina in the metazone. In this species, the antennae are shorter than the head, plus the pronotum and tegmina with two transverse pale fascias tapering sharply in the median field (Louveaux et al., 1996).

In addition, Louveau notes the presence of less than 9 spines on the outer edge of the femur and 10 spines on the inner side. While others normally count10 spines on the outer edge and 11 spines on the inner edge (Defaut and Jaulin, 2008). However, Mazurier and al. mentioned that the posterior femora of this species is three times longer than wide, with a maximum width located at one-third of the length of the femur, the posterior tibia often of a purple color. The posterior femurs are very swollen, the tegmina adorned with large dark macules and provided with large dark spots (DUSOULIE, 1996). This species is marked by the presence of two more or less marked dark rings on the posterior tibiae (Rochelle et al., 2013). In this case, the intraspecific separation is developed recently by Bughio thanks to the phallic complex, citing certain distinctive characteristics such as the shape of the penis in relation to the valve of the cingulum (Bughio et al., 2014).

2. *Euchorthippus elegantulus:* For Chopard, *Euchorthippus elegantulus* is characterized by a more or less long head with less swollen cheeks (Chopard, 1943b). In this species, the vertex with an obtuse apex and the lateral keels extended behind the eyes. Likewise, Louveau in addition to noticing the flat shape of the pronotum and the straight, parallel and slightly divergent lateral keels in the metazone. He focusedthe identification of this species on the shape of the flattened antennae in the basal half, the rounded shape of the vertex with carinules behind the eyes. Long and narrow posterior femora and the tigmina reaching in females or exceeding in males the apex of the posterior knees. Moreover, the resemblance of the genus *Euchorthippus* and *Chorthippus* is moreover of such a point that it is sometimes almost impossible to make the distinction (Defaut, 2012).

3. *Chorthippus albomarginatus:* *Chorthippus albomarginatus* light green or tested with two dark side bands more or less marked. The male sub-genital plaque of this species is short, curved or hairy. Chopard mentions that the elytra of this species reach the tip of the abdomen. While, Louveau merely added to Chopard's description the device of the stridulatory apparatus present in the male and often in the female in the form of a tuber comb articulated on the inner surface of the posterior femur (Chopard, 1943b). Temporal foveoli with sharp edges; pronotum with straight, parallel,

concolorous lateral keels; typical furrow in the middle. In both sexes, green or testaceous, with an opaque whitish band, more or less marked, in the scapular field in female's transparent wings. Medium sized cub with a small basal lobe on the costal edge of the tegmen Front and vertex form an acute angle. In 2009, Vedenina, foresees another track of sound characterization. For him, the grasshopper species of the *Chorthippus albomarginatus* group represent an interesting species complex with quite similar morphology and simple, similar call songs, but extremely different and complex courtship songs (Vedenina et al., 2009; Vedenina and Von Helversen, 2003). More recently, Rolando based on the vining of the forewings,found that the radial vein is clearly curved in males, and the overlying radial field is widened in the middle of the wing. Another unifying, yet acoustic, feature of the two species is the males' spontaneous song, which consists of an average of three successive purring couplets, lasting about 0.5 seconds, that are performed at intervals of 2- 3 seconds (Teruel, 2018).

iii. Truxalinae subfamily

For Dirsh, it is difficult to decide whether to belong to this subfamily because the phallic complex of Acridinae and Truxalinae does not provide sufficiently clear separation characteristics. In addition, the presence in some genera of a prosternal organ binds them to the Catantopinae. However, it is important to distinguish them by the absence of stridulatory structures on the inner surface of the posterior femur (Dirsh, 1956). mOther authors, such as M. Locoq, based their description of the *Truxalinae* subfamily primarily on the elongated body shape, with a very conical head with ensiform antennae. The femurs are very long and very thin. In this case, they mention the presence of stridulatory hairs carried by rigid tubercles on the inner surface of the posterior femurs and the disappearance of the external apical spine on the posterior tibias. In fact, the close relationship between the two genera Acrida in *Acridinae* and *Truxalis* in *Truxalinae* has also been mentioned by Chapco and Contreras (Chapco and Contreras, 2011). This finding supports Jago's synonymy of *Truxalinae* under *Acridinae* (Jago, 1966). Indeed, both genera have an elongated body, strongly ensiform antennae and a strongly inclined head. Based on the phylogeny, the absence of stridulatory structures in Acrida seems to be a loss of character (Song et al., 2018).

1. *Truxalis nasuta:* Species belonging to this genus without a menu of lamellar expansions on the medial side of the posterior femur, allowing serving as stridulatory tools (Kumar and Usmani, 2014). However, Usmani predicts that the epiphallus has a narrow, undivided bridge in this species. Especially since the ancorae has a small anterior expansion with an obtuse apex, the narrow posterior expansion with an acute apex, in T. nasuta the bilobed lophi, the lobes are close to each other (Usmani, 2017).

iv. Calliptaminae subfamily

The genera belonging to this subfamily have well-developed flight organs,pronotum with the obtuse posterior edge. They are usually short and thick in shape. Vertex broad, obtuse. Disc flat with low but well-marked keels, prosternal tubercle cylindrical. Elytra and wings are well developed. Thick posterior femora. In males, the last abdominal segment is compressed into a curved blade, ending in a large rounded, and strongly swollen upper lobe.

1. *Calliptamus barbarus:* Its range extends from Portugal in the west to Afghanistan and China in the east (Fabry et al., 1987; Larrosa et al., 2007) and from northern Russia (Stolyarov, 2000) to Pakistan in the south, through Europe, the Mediterranean sea and North Africa and the Middle East. This species presents a chromatic polymorphism at the level of the posterior femora, ruby color with three frank and separated femoral spots or pale orange of only one big femoral spot, seeming to have a relationship with its ecological distribution and its habitat. The form with one femoral spot is found almost exclusively in semi-arid environments, while the form with three spots is found in less arid locations (Rouibah et al., 2016)or only one hind femoral spot. Many authors have tried to compare the two forms on the basis of morphology. And they noticed that the single femoral spot form is larger than the three spot form for both males and females(Clemente et al., 1987; Larrosa et al., 2007; Louveaux, 1991).

The behavior of acoustic emissions in *C. barbarus* of males, and to a lesser degree of females,the length of the syllable and the number of pulses emitted are greater in the one-spot form than in the three-spot form. Larrosa and al reported that(Larrosa et al., 2007), with respect to sexual behavior, there are some differences between the two forms in inter and intra-sexual relations (twitching and alternating movement of the posterior femurs, up and down walking of the posterior femurs, advance and jump) and proposed that both forms seem to follow a process of speciation (Larrosa et al., 2007). In the same direction, some differences between these

two forms with regard to the total proteins and the enzymatic systems of the haemolymph and the wing muscle have been reported (Benzara, 2004).

2. *Calliptamus italicus:* According to Chopard the posterior femurs of this species are marked with 2 or 3 brown fascia on the internal face; the male genital organ is very elongated. The elytra in this macroptera have long parallel edges reaching at least the end of the abdomen, with a pronotum with post-angular edges. In this species, based on molecular marker techniques, high levels of genetic diversity have been observed (Blanchet, 2009).

3. *Calliptamus wattenwylianus:* Short and thick in shape and with elytra never reaching the end of the abdomen. Some authors have become accustomed to drawing up certain reports to differentiate between species or between subspecies of the same genus as such Jago showed that *C. italicus* and *C. barbarus* had a higher wing/body length ratio than *C. wattenwylianus*. This ratio makes it possible to estimate the dispersal capacity. In these works, he demonstrated that the dispersal behavior seems to be more restricted in *C. wattenwylianus* compared to the first two. Its range is limited to the Mediterranean carriers, particularly northern Africa. Moreover, this species is among the most limited Calliptamus((Blanchet, 2009; Chara, 1987).

v. *Gomphocerinae* subfamily

Gomphocerinae Tarbinsky, 1932 occupies lowland grasslands, steppes, open forests, and high mountains; it is one of the most widespread subfamilies of *Acrididae* among the *Orthoptera*. *Gomphocerinae* grasshoppers are reported to comprise nearly 1350 taxa (species/ subspecies) (Abbas and Zeybekoğlu, 2013). Songs can be a useful tool for species identification and may contain important taxonomic information (Şirn and Mol, 2013); formerly called *Gomphoceriduis* by Chopard. The latter focuses on the lobiform, lateral elytra. These elytra reach or exceed the abdominal extremity. While Jago insists on describing the *Gomphocerinae* on the femoro-tegminal stridulatory mechanisms consisting of a row of modified peg-shaped spines mounted on the lower edge of the inner zone of each posterior femur. This spine bung strikes the folded tegmen's raised first radial vein (RI).

More recently, Default adds that the absence of a tubercle at the pronotum level is one of the descriptive characteristics of the sub-family, but to a much lesser extent (Defaut, 1999). Contrary to the meticulous morphological description of many taxonomists such as (Chapco and Contreras, 2011; Chopard, 1943b; Dirsh, 1975; Jago, 1963; Rowell and Hemp, 2017). Some authors reject the higher number of genera belonging to this subfamily, based on the molecular tool (Song et al., 2018).

1. *Dociostaurus genei:* Before the appearance of the Soltani publications in 1978, this species was called *Stauronotus genei Ocskay* or *Dociostarus genei Ocskay* (Soltani, 1978). This species with a pronotum marked with a clearly visible cross pattern, especially at the level of the metazone, surrounded by blackish brown. Chopard, in these works on the *Orthoptera* of North Africa, points out that the pronotum of this species is short, constricted, and furrowed in the middle. The posterior femora with three external triangular spots, generally well-marked (Chopard, 1943a). In Morocco, this species is very similar to *Dociostaurus. jagoi* (Soltani). The few differences that Defaut reports indicate, on the one hand, the shape of the apical valves of the penis, which are slender in *D. genei* (Ocskay) and stocky in *D. jagoi,* and the length of the penis, on the other hand, the number of teeth on the stridulatory combs at the level of the posterior femurs (Defaut, 2004).

2. *Dociostaurus maroccanus:* *Dociostaurus maroccanus,* or Moroccan locust, was first discovered by Thunberg in 1815 in the Moroccan Atlas Mountains (Moussi et al., 2014). It is a rufous testacean, with a furrowed pronotum in the middle, partly transparent elytra except for a few brown spots, a long but truncated subgenital plate of the male at the end, long conical cerci and a reddish tibia with a yellow ring at the base. In 1921 Uvarov, was based on certain measurements such as the length of the body, the languor of the elytra, and the dimensions of other organs. It revealed the presence of three characteristic black spots on the posterior femurs (Uvarov, 1921). These same characters were later verified by Chopard by adding another more exciting character, that of a very remarkable yellowish cross pattern at the level of the pronotum (Chopard, 1951).

Most taxonomic efforts on the group have focused on morphological and bioacoustic cue diagnostics ((Harz and Kaltenbach, 1976; M. D. Gracia, Esther Larrosa, 2005; Soltani, 1978). However, based on the tools of phylogeny, this genus includes 30 described species and three subgenera separated by certain morphological traits: 16 species in the subgenus *Dociostaurus Fieber* (GonzÁlez-Serna et al., 2018)such approaches are invaluable for urgent assessment and delimitation

of truthful species, particularly of endangered and morphologically cryptic taxa from vulnerable areas submitted to strong climate change and progressive human intervention such as the Mediterranean region. In this study, we applied two DNA-based species delimitation methods and performed a Bayesian phylogenetic reconstruction using three mitochondrial gene fragments (12S, 16S and COI.

II. *Pyrgomorphidae* families

The *Pyrgomorphidae* (*Orthoptera: Caelifera*) constitutes one of the most charismatic families of grasshoppers, well known for their vibrant body color and conspicuous carved patterns on the pronotum(MariÑo-PÉrez and Song, 2018). The family currently includes 487 valid species, the vast majority of which (384 species) are distributed in Africa and Asia (Mariño-Pérez and Song, 2019). According to Chopard, the genera of this family have the head of a conical shape, the prosternum is equipped with a spine or tubercle, which can be formed by the front edge. The vertex is more or less prolonged in a horizontal blade in front of the eyes (Chopard, 1922). As for Default, while revealing the same characteristics as Chopard, he mentions that the salient vertex forms an acute angle with the forehead while raising the absence of Krauss' organ. More recently, Shahnila Usmani underlines the presence of dorso-lateral appendages in the family *Pyrgomorphidae* (Usmani, 2017).

i. Pyrgomorphinae subfamily

In the *Pyrgomorphinae* according to Dirsh, the body is generally more or less cylindrical. At the level of the posterior femora, the lower lobe is longer than the upper lobe. In all genera of *Pyrgomorphinae,* the epiphallus has complementary lateral lobes, which are absent in other subfamilies of Acrididae (Dirsh, 1952). In addition to the characteristics invoked previously, Kevan specifies that the metasternal fossae generally are small and connected by two sutures. Pronotum sometimes with large tubercles. The predominance of circumtropical and subtropical regions, some extending to the Palearctic region, is very strongly represented in Africa (Kevan and Akbar, 1964).

1. *Pyrgomorpha agarena:* Recognized by a punctate and rough pronotum, but not granular; a sinuate lower banded lateral lobe rounded posterior angle. Top of vertex no longer than wide, with parallel edges; top of the head. Antennae are short, not reaching the posterior edge of the pronotum. Elytra reaching the apex of the abdomen or slightly shorter, with very tight longitudinal ribs, and almost absent transverse veins (Chopard, 1943b). Recognizable by a punctuated and rough pronotum, but not granular; a sinuous lower lateral lobe with rounded posterior bands. Top of the top not longer than wide, When it came to Louveau, he emphasized certain rather relevant detail, such as the presence of very small spines on the lateral lobes of the pronotum, and the keels of the pronotum, which are not very visible. The hind femora in this species, as described by many taxonomists, does not extend beyond the end of the abdomen (Louveaux et al., 2013). Other authors, such as Massa emphasize the absence of dots or granules on the head and pronotum and confirm that in females, the mesosternal space is wider than long, and the tegmina reach or slightly exceed the end of the abdomen (Massa, 2009). The microptera form or *Pyrgomorpha. agarena*, characterized by a shortening of the flight organs compared to the macropterous form occupying the altitudes or *P. a. vosseleri*. According to Default, the latter can be considered a species in its own right and can even support the presence of a subspecies *P. vosseleri subconica*(Defaut, 2017)which was once considered a valid species by Massa (Massa, 2009).

III. Pamphagidae families

For individuals representing this family, Chopard had highlighted a relevant character at the level of the second abdominal tergite, the latter presenting the Krauss organ on the sides, and also noted the extension of the furrow on the frontal side up to the vertex (Chopard, 1943a). For some authors like Kevan the phallic complex is a strong point for the identification of genera belonging to the *Pyrgomorphidae*. Thus, the epiphallus is attached to its distal and lateral ends by the apex of the cingulum or by the ectophallic membrane and the pallium, respectively. The lateral prolongations (LP) are hard connected at their base to the lateral borders of the cingulum. Strongly sclerotized crests, almost anteroposterior, most often reinforce the first, and the second are armed with small spiny extensions. The anterior extensions (AP) are small, broadly rounded lobes, sometimes slightly narrowed at the base, or long, slender claws (Kevan et al., 1968).

The only subfamily represented in the Middle Atlas is that of *Pamphagidae*. The latter has three species belonging to three genera.

i. Pamphaginae subfamily

Of all the *Pamphagidae* subfamilies, this is probably the most heterogeneous. Almost 60% of the species are encountered in in North-West Africa are found in Morocco (Louveaux and ben Halima, 1986).

1. *Pamphagus* sp.: *Pamphagus Thunberg*, 1815, this small to large species is characterized for Dirsh from a morphological point of view by a compressed to the depressed body, filiform, ribbon or slightly ensiform antennae. The shape of the depressed pronotum in a fine crest, the prozone is always longer than the metazone. He also highlighted the laterally lobiform shape of the wings and elytra in species of this genus with the absence of tympanic organs and the presence of Krauss's organ (Dirsh, 1961). The pronotum in this species, according to Louveau has a high and arched median carina and the transverse furrow, if present, intersectsthe median carina in the posterior quarter. The posterior femora are slender and the integument is slightly tuberculate and smooth (Louveaux and ben Halima, 1986).

2. *Ocnerodes* sp.: Usually Chopard from a purely morphological angle. He confirms that in species of this genus the head is more or less rough, and behind the eyes, there are remarkable wrinkles. The tectiform pronotum is angular in front, with median carina uninterrupted by the typical furrow. the elytra are also emphasized;these are short, narrow, and widened at the apex (Chopard, 1943b). Llorente and *al*., have reported to a relevant character which is the number of articles at the level of the antennas. In this species, there are 13 to 18 joints. These antennae are filiform or flattened at the base, reaching in the 8th segment the posterior furrow or the posterior edge of the pronotum. Also, the eyes in the dorsal view are oval in shape, with a space between the eyes equal to or greater than the length of the eye (PRESA, 1983). More recently, Louveau described this micropterous or wingless species, highlighting the shape of the ventral valves of the ovipositor. The latter is in the form of a large triangular tooth (Louveaux et al., 2013).

3. *Paraeumigus parvulus:* With the top of the vertex flat and grainy in the female. Chopard differentiates *Paraeumigus parvulus* from *Euryparyphes sp* mainly by the shape of the prosternal tubercle which is bidentate at the anterior edge of the prosternum. Also, he notices that the crest of the pronutom very low and straight. Concerning the elytra, they are oval and narrow, with straight anterior edges, and inner edge broadly bordered with yellow in the disease (Chopard, 1943a). From a form point of view. Louveau, stipulates that the size of females is much larger and uniformly colored than males with rough integuments, a basic morphological character. Hind tibia in both sexes wia th yellow inner surface and pale black-tipped spines. Recently, Massa enumerates the characteristics linked especially to the phallic complex, the latter shows a very short apex and wide and non-pedunculated aedeagus valves. In females, the mesosternal space is twice as wide as the length, and the mesosternal spisace is two to two and a half times as wide as long (Massa, 2013). Other authors have noticed that *Paraeumigus parvulus*, based on the phylogeny, belongs to the same clade of *Eunapiodes sp.* (SUKHIKHIKH, 2020).

CONCLUSIONS

Based on old and recent literature, the present study has updated the taxonomic treatment of the Middle Atlas Caelifera. Knowing that the most important Caelifera superfamily is the Acridoidea superfamily (Song et al., 2010). We have tried to make our contribution, by identifying the species that exist in the Moroccan Middle Atlas. However, the inventory of Orthoptera in the study region is still far from being exhaustive and it remains incomplete and needs to be continued. In this section, we have seen that Acrididae have been used as a systematic dump for unrelated taxa where the authors cannot distinguish them. Hence the proposal of a distinctive structure, in the form of an arched sclerite at the level of the male phallic complex in all the elements of this family. An element almost absent in most families belonging to Acridoidea (Eades, 2000). According to some studies, the molecular tool has been able to establish similarities between Pyrgomorphidae and Acridoidea as a whole (Song et al., 2015). While Pyrgomorphidae were considered members of Acridoidea. And it is in this respect that we must claim the identification and separation of certain families based solely and essentially on the morphological character. Thus, other studies, either on the phallic complex or by moving on to molecular deciphering, could be carried out to resolve the taxonomy of certain difficult species and help to better understand the evolutionary relationships and establish the association of the habitat with various ecotypes. at the level of the Moroccan Middle Atlas.

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