

Disentangling the distribution of *Tettigonia viridissima* (Linnaeus, 1758) in the eastern part of Eurasia using acoustical and morphological data

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Abstract

Tettigonia viridissima is a species that is widely distributed throughout the Palearctic. For decades it was assumed that the eastern range limit of the species reaches until the Pacific Coast of the Eurasian continent. However, STOROZHENKO (1994) provided evidence for the assumption that *T. viridissima* reaches its eastern distribution border at the Altai Mts. Based on this study the long winged *Tettigonia* species living in the eastern most part of Eurasia must be classified as *Tettigonia dolichoptera* on the mainland and as *Tettigonia orientalis* (or other *Tettigonia* species of the *T. orientalis* group) in Japan. The three species *T. viridissima*, *T. dolichoptera* and *T. orientalis* are similar with respect to wing length, but they can be clearly distinguished by cercus length, shape of tegmina and song traits.

Zusammenfassung

Tettigonia viridissima ist eine paläarktische Art, die jedoch nicht bis zur Pazifikküste des eurasischen Kontinents vorkommt. Die östliche Grenze ihres Vorkommens liegt nach STOROZHENKO (1994) im Altai-Gebirge, aber diese Information wurde lange übersehen. Anhand der vorliegenden Studie müssen langflügelige *Tettigonia*-Arten im Fernen Osten auf dem Festland als *Tettigonia dolichoptera* und in Japan als *Tettigonia orientalis* (oder als andere *Tettigonia*-Arten, die zur *T. orientalis* Gruppe gehören) klassifiziert werden. Die drei Arten *T. viridissima*, *T. dolichoptera* und *T. orientalis* sind sich ähnlich in ihrer Flügelänge, können aber anhand der Länge der Cerci, der Form der Tegmina und dem Gesang klar unterschieden werden.

Introduction

The great green bush-cricket *Tettigonia viridissima* (Linnaeus, 1758) distributed in wide parts of the Western Palearctic is one of the largest bush-cricket species of the Eurasian continent. However, its distribution in the Eastern Palearctic has been unclear for quite a long time. Occurrence of the species at the Pacific Coast of the continent (mainland) and Japan has been mentioned in several taxonomic studies (UVAROV 1924, BEY-BIENKO 1929, MORI 1933, CHO 1959, HARZ 1969 ("Holo-Palearctic"), LEE 1990, MOON & YOON 1993) and more recently in some works dealing with the local distribution of the species in Europe (e.g., DETZEL 1998, SCHLUMPRECHT & WAEBER 2003, BAUER et al. 2006, ZUNA-KRATKY et al. 2009, PFEIFER et al. 2011). STOROZHENKO and others, however, provided evidence that *Tettigonia viridissima* does not occur in this region (STOROZHENKO

1994, STOROZHENKO & PAIK 2007, KIM 2009, KIM 2010). In this work, I will present information on the history of the misidentification of *Tettigonia viridissima* in North-east Asia, and will support STOROZHENKO's and KIM's results that all long-winged *Tettigonia* in North-east Asia must be identified either as *Tettigonia dolichoptera* or *Tettigonia orientalis* (or other *Tettigonia* species of the *T. orientalis* group in Japan). For this purpose I will present data on song and morphological features of *Tettigonia viridissima*, *T. dolichoptera* and *T. orientalis*. About morphology, song and distribution of *Tettigonia chinensis* Willemse, 1933 there are too few data for a comparison. According to STOROZHENKO (1994), it occurs in the southern part of China (Guangdong, Sichuan, Kiangsi).

History of misidentification of *Tettigonia viridissima* in North-east Asia

In 1924, UVAROV mentioned the distribution of *Tettigonia viridissima* in North-east Asia for the first time, based on two males, which belong to the British Museum collections and are labelled "Seoul Korea" (UVAROV 1924). Furthermore, according to OGAWA & OHBAYASHI (2003), BEY-BIENKO (1929) recorded *T. viridissima* based on one male and two females of the species in Japan. In 1933 MORI described (in Japanese language) a new species of *Tettigonia* in Korea as *Tettigonia dolichoptera* which has long wings and long hind femora. In this work he also mentioned *Tettigonia viridissima* as having a smaller body size and shorter wings compared to his new species. Probably he did not know *Tettigonia viridissima* exactly as a consequence of lack of scientific contacts between Europe and Asia at that time. He may have misidentified *Tettigonia ussuriana* Uvarov, 1939 or a form of his new species with shorter tegmina as *Tettigonia viridissima*. After this work, in 1959 Cho who was the first Korean entomologist who followed Mori's work (in Korean with some old Chinese signs; CHO 1959) because he was a student by Mori in Japanese colonial period in Korea. In Europe, HARZ (1969) described the distribution of *Tettigonia viridissima* as Holo-Palearctic without a detailed description which was correct following the interpretation of UVAROV (1924). EBNER (1946), however, had already raised the question if the three European species – *T. cantans*, *T. caudata*, *T. viridissima* – occur actually also in central Asia and eastwards. RENTZ & MILLER (1971) mentioned recently collected *T. dolichoptera* from Korea without any measurements. In 1990, LEE synonymized *Tettigonia dolichoptera* with *T. viridissima*. After Lee's work, MOON & YOON (1993) mentioned *T. viridissima* again because Moon studied at a university in the United Kingdom, hence, he just followed European references. However, STOROZHENKO (1994) found out that the long winged form of *Tettigonia* in the North-east Asian mainland must be identified as *Tettigonia dolichoptera* and gave details about form and length of wings and cerci. In the meantime this opinion has been supported by KIM & KIM 2001, STOROZHENKO & PAIK 2007, KIM 2009 and KIM 2010.

Materials and Methods

Morphology and distribution of the three species in question are described in several studies: *T. viridissima* (e.g., HARZ 1969), *T. dolichoptera* (STOROZHENKO 1994, STOROZHENKO & PAIK 2007), and *T. orientalis* (UVAROV 1924, OGAWA &

OHBAYASHI 2003). Also the song of *T. viridissima* and *T. dolichoptera* has been published (e.g., HELLER 1988, RAGGE & REYNOLDS 1998, KIM 2009, KIM 2010) and the song of *T. orientalis* has been described by OGAWA & OHBAYASHI (2003) and later published on CD by ICHIKAWA et al. (2006). My own records of *T. viridissima* and *T. dolichoptera* agree with these data.

For the measurements, description and figures I have used specimens and recordings from my collection. However, I do not have specimens of *Tettigonia orientalis*, therefore, I consulted the notes from UVAROV and STOROZHENKO and OGAWA & OHBAYASHI for description and used the CD data from ICHIKAWA et al.

T. viridissima:

Germany: 4 males 17.6.2011, Berlin Airport Tempelhof; 5 males and 3 females 28.6.2011, Colbitz Lower Saxony; 1 male 29.6.2011, Magdeburg Lower Saxony.

Greece: 2 males and 1 female from 24.6 to 15.7.2009, Paleokastro Hagios Georgios, Central Greece.

T. dolichoptera:

South Korea: 2 males and 1 female 29.7.2007, Gyeonggi-do Incheon Onjingun Island of Muui; 1 male 26.6.2003, Gyeonggi-do Yangju-gun Jangheung-myeon Wudaeri; 2 males 19.7.2006, Gyeonggi-do Yangju-gun Jangheung-myeon Wudaeri.

To measure the body size, I used a 15 cm ruler for both species. The songs were recorded from captive animals on a balcony or during bush-cricket catching time with a Samsung Mp3, Nikon Coolpix 4500 camera as video (*T. viridissima*) or a custom computer microphone (*T. dolichoptera*). In addition, some data on the eastern border of *Tettigonia viridissima* in Asia were provided by STOROZHENKO (pers. comm.).

Results

Morphological description of *Tettigonia viridissima* (Linnaeus, 1758)

(Fig. 7a, b, c, d)

The body is green or yellowish brown. Sometimes the whole body is green but only all femora are light brown. There is a clear dark stripe on the dorsal parts from head to metazona with a dark yellow or yellowish spot between the stripes at sulcus (Fig. 5a). The colour of the stripe and its extension over the tegmina is variable (red brown or brown or dark brown or black or brown with black spot). The tegmina surpass the hind femora obviously (Fig. 6a). The front of the male stridulatory apparatus is rounded but sharply at the end (Fig. 4a). The cerci of the male are almost two times longer than the styli and the inner teeth are located within the basal one-third (Fig. 8a and Fig. 9a). The ovipositor of the female is slightly curved and does not reach behind the wingtip.

Measurements: See Table 1.

Distribution (STOROZHENKO 1994, CHILDEBAEV & STOROZHENKO 2004): North Africa, Europe, Asia Minor, Caucasus, Afghanistan, North India, Central Asia, Kazakhstan, North-west China (Tian-Shan), West Siberia (from Ural to Altai Mts.) and - possibly - North Mongolia (Fig. 3).

Data for the eastern border of the range provided by STOROZHENKO (pers. comm.): West Siberia, Altai Mts., Pankrushikha, ca 300 km SE from Barnaul, 2 females [Zoological Institute of the Russian Academy of Sciences, St. Petersburg]. Altai (TARBINSKY, 1925: 178): vicinity of Barnaul, 2-27 August 1923 (number of studied specimens not recorded).

Morphological description of *Tettigonia dolichoptera* Mori, 1933

(Fig. 7e, f).

The body is usually green, only rarely with light brown femora. There is an indistinct spot or a light indistinct stripe on the back of the head or the frontal part of the pronotum or both of them, but not on the metazona, only rarely a indistinct stripe on it (Fig.5b). The colour of the spot or stripe is black or red brown or light brown. The tegmina surpass the femora, but not obviously. At one third of the distance from the wing basis towards its tip, the wing is wider than at the beginning of its apical third, which is similar to *T. orientalis* (Fig.6b). The male stridulatory apparatus is slightly triangular (Fig. 4b) The styli of the males extend to about half the length of the cerci and the inner tooth of cerci are covered by an epiproct, which is longer than in *T. viridissima* (Fig.8b). The ovipositor of the females is straight and about half of its length extends over the wingtip.

Measurements: See Table 1. (Fig. 1)

Distribution (MORI 1933, STOROZHENKO 1994, KIM & KIM 2001, STOROZHENKO & PAIK 2007): South Korea (without southern islands), North Korea, Manchuria, North-eastern China, Pacific Coast of eastern Russia (Fig. 3).

The syntypes of Mori were lost during the Korean War. However, the measurements of KIM & KIM (2001) demonstrate clearly that Mori had used unusually large specimens as types, probably to have a clear difference to his "*T. viridissima*" which may have been *T. ussuriana*. Most Korean specimens are distinctly smaller (Fig. 1). So the validity of the smaller subspecies *T. d. maritima* from the Russian Far East has to be considered as doubtful. In addition, it would be only a junior synonym of *T. uvarovi* Ebner, 1946. STOROZHENKO (1981) synonymised *T. uvarovi* with *T. ussuriana*; however, applying his own key (STOROZHENKO & PAIK 2007) on the type reveals clearly that it belongs to *T. dolichoptera* (Fig. 1).

Description of *Tettigonia orientalis* Uvarov, 1924

According to UVAROV (1924) and STOROZHENKO (1994), the tegmina slightly surpass the hind femur and the basal third of the tegmina is wider than its apical third. The length of it is quite variable (data in OGAWA and OHYBAYASHI 2003). The cerci of the species are shorter than in *T. viridissima* and extend to the ends of the styli (Fig. 8c).

Measurements: See Table 1.

Distribution (UVAROV 1924, STOROZHENKO 1994, OGAWA and OHYBAYASHI 2003, ICHIKAWA et al. 2006): Japan; Honshu and Shikoku (Fig. 3). Not in Korea (compare between STOROZHENKO & PAIK 2007 and PAIK et al. 2010).

Table 1: Comparative measurements of the three *Tettigonia* species.

| Species Reference | Hind Femur [mm] | | Pronotum [mm] | | Tegmina [mm] | |
|---|-----------------|-----------|---------------|--------|--------------|---------|
| | male | female | male | female | male | female |
| <i>T. viridissima</i> HARZ (1969) | 22-28 | 25-29.5 | 6-9 | 8-9 | 34-47.5 | 43-54 |
| <i>T. viridissima</i> STOROZHENKO (1994) | 22.3-28 | 25.3-29.5 | 7.-8.5 | 7.2-9 | 40-47.5 | 44-53.5 |
| <i>T. viridissima</i> Own data | 21-27 | 25-30 | 6.5-9 | 7-9.5 | 40-50 | 49-57 |
| <i>T. viridissima</i> MORI (1933) = <i>T. ussuriana</i> ? | 22-24 | 24-26 | 7-7.5 | 8-8.5 | 28-34 | 27-32 |
| <i>T. dolichoptera</i> <i>maritima</i> STOROZHENKO (1994) | 24-25.1 | 24.5-29.2 | 7.9-8.2 | 8-9.1 | 37.5-38.5 | 36-43 |
| <i>T. dolichoptera</i> Own data | 25-30 | 30 | 7.5-9 | 9 | 40-45 | 42 |
| <i>T. dolichoptera</i> MORI (1933) | 31 | 29 | 9 | 8 | 47 | 45 |
| <i>T. orientalis</i> UVAROV (1924) | 27 | 28 | 9 | | 33.5 | 38 |
| <i>T. orientalis</i> OGAWA & OHBAYASHI (2003) | 25.6-31.1 | 28-33.2 | 8.2-10.4 | 9-10.5 | 33.5-40.8 | 38-40.8 |

Song of *Tettigonia viridissima* (Linnaeus, 1758)

The song type is a continuous trill, which is often broken by short gaps at larger, irregular intervals (not shown; see also HELLER 1988, RAGGE & REYNOLDS 1998). The syllables are always arranged in pairs: Between first and second syllable there is a short gap, after the second syllable, there is a larger one. This pattern is repeated continuously. The song can be heard from late afternoon to night. (Fig. 2a, b). According to INGRISCH & KÖHLER (1998), as a result of NIELSON & DREISIG (1970), the beginning time of the song depends on temperature.

Song of *Tettigonia dolichoptera* Mori, 1933

The song is a continuous trill which may last for many seconds (see also KIM 2009) (Fig. 2c). It can be heard in the night usually and habitually, both males and females have a break time in the bush during the day, but if there is hard wind at the day, suddenly, males sing reflected tone (?), warming up tone (?) and come out into above bush to move into other place, that is somewhat similar to Heller's work about *Hexacentrus unicolor* Serville, 1831 (HELLER 1986). However, this song is not introduced in this work because of lack of data. Thus, I will examine this song in the future.

Song of *Tettigonia orientalis* Uvarov, 1924

The song is a continuous homogenous trill lasting for many seconds (syllable repetition rate 36 Hz at 30 °C; OGAWA & OHBAYASHI 2003). In the recording shown here the opening hemisyllables are clearly visible (Fig. 2d).

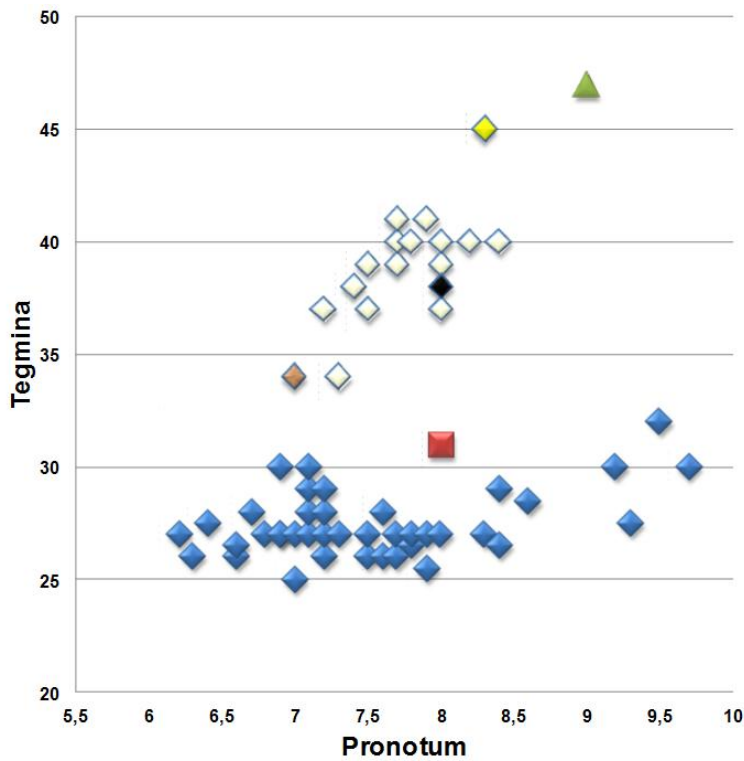


Fig. 1: Measurements of Korean *Tettigonia* (mainly from KIM & KIM 2001, supplemented with the data of the types of *T. uvarovi* and *T. d. maritima* and own data). Blue: *Tettigonia ussuriana* in South Korea.; Red: Holotype of *Tettigonia ussuriana*; White: *Tettigonia dolichoptera* in South Korea; Green: Syntype of *Tettigonia dolichoptera*; Grey: one specimen of own *Tettigonia dolichoptera*; Black: Holotype of *Tettigonia dolichoptera maritima*; Brown: Holotype of *Tettigonia uvarovi*.

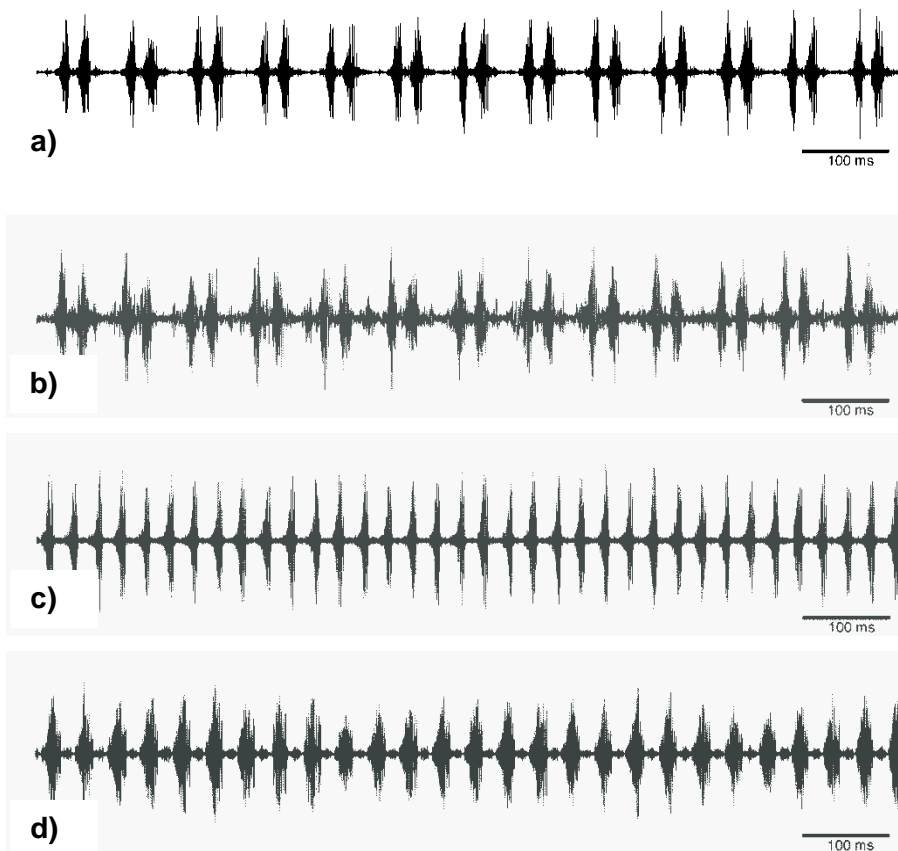


Fig. 2: Oszillogram of songs of (a) an isolated male of *T. viridissima*, (b) two males of *T. viridissima*, (c) *T. dolichoptera* (d) *T. orientalis*. (a) Isolated male in the cage recorded by Samsung Mp3 in Germany in Berlin 2.7.2008 on 23:30 at 20 °C; (b) two males singing with distance in *Urtica* sp. recorded by Nikon Coolpix 4500 camera as video in Greece in Paleokastro Hagios Georgios; (c) isolated male in the cage South Korea, Seoul 6.7.2003 on 23:00 at 29 °C; (d) Recording from CD in ICHIKAWA et. al (2006), 26.5 °C.



Fig. 3: Distribution of three *Tettigonia* species in Northeast Asia: 1) *Tettigonia viridissima* (Linneaus, 1758); 2) *Tettigonia dolichoptera* Mori, 1933; 3) *Tettigonia orientalis* Uvarov, 1924.

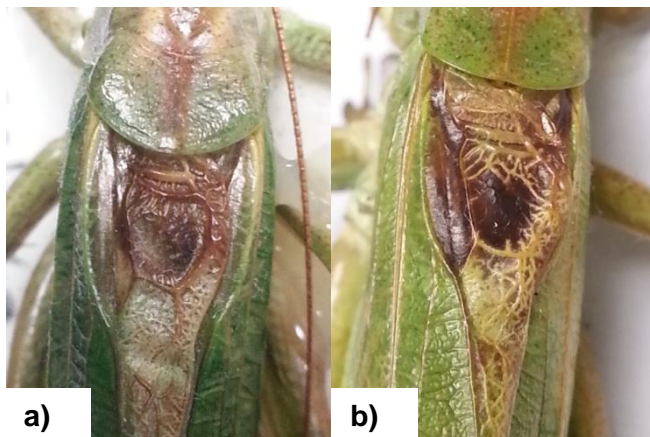


Fig. 4: (a) stridulatory apparatus of *Tettigonia viridissima*. (b) *Tettigonia dolichoptera*.

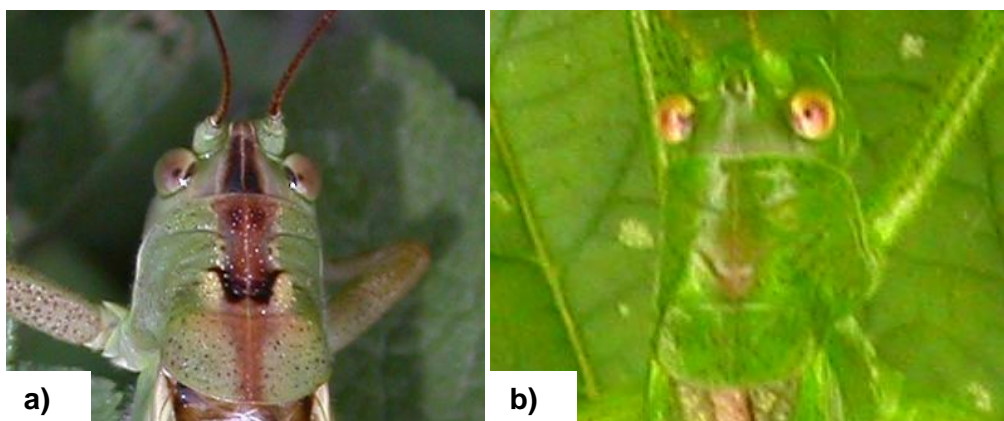


Fig. 5: (a) dorsal view of *Tettigonia viridissima*. (b) *Tettigonia dolichoptera*.



Fig. 6: Tegmina of (a) *Tettigonia viridissima*, (b) *Tettigonia dolichoptera*.

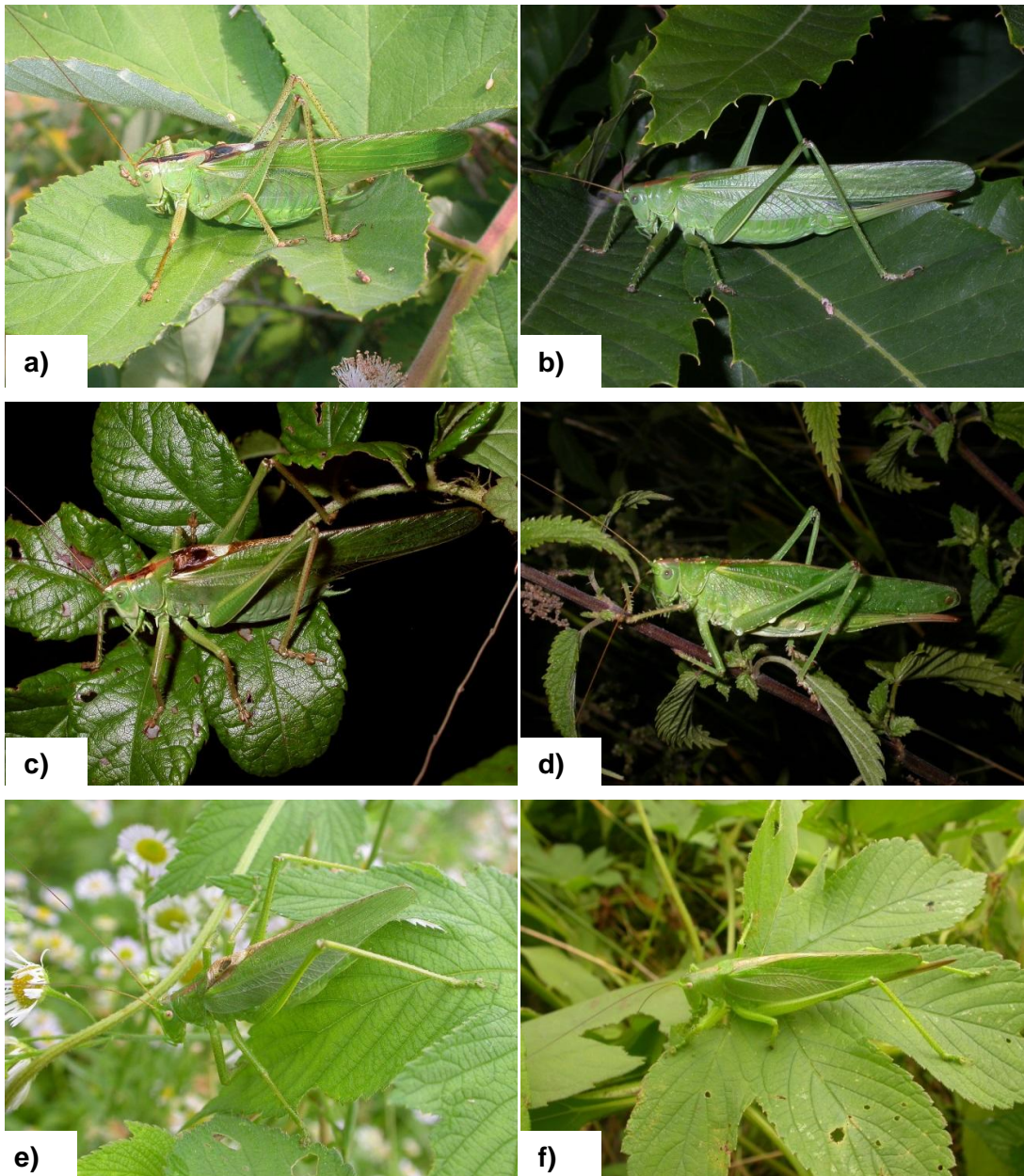


Fig 7: *Tettigonia viridissima* (a) Male, Greece; (b) Female, Paleokastro Hagios Georgios. (c) Germany Male 14.8.2009 Berlin Wuhletal; (d) Female 3.8.2010 Berlin Airport Tempelhof. *Tettigonia dolichoptera* South Korea (e) Male, (f) Female Gyeonggi-do Yangju-gun Jangheung-myeon Wudaeri on 14.7.2006 and on 19.7.2006.

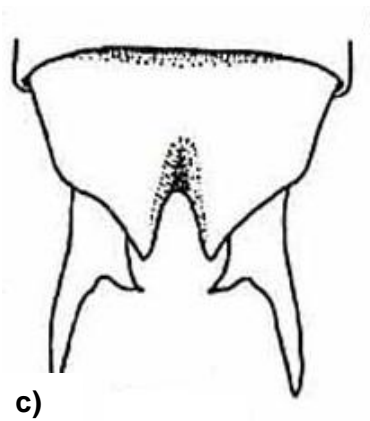
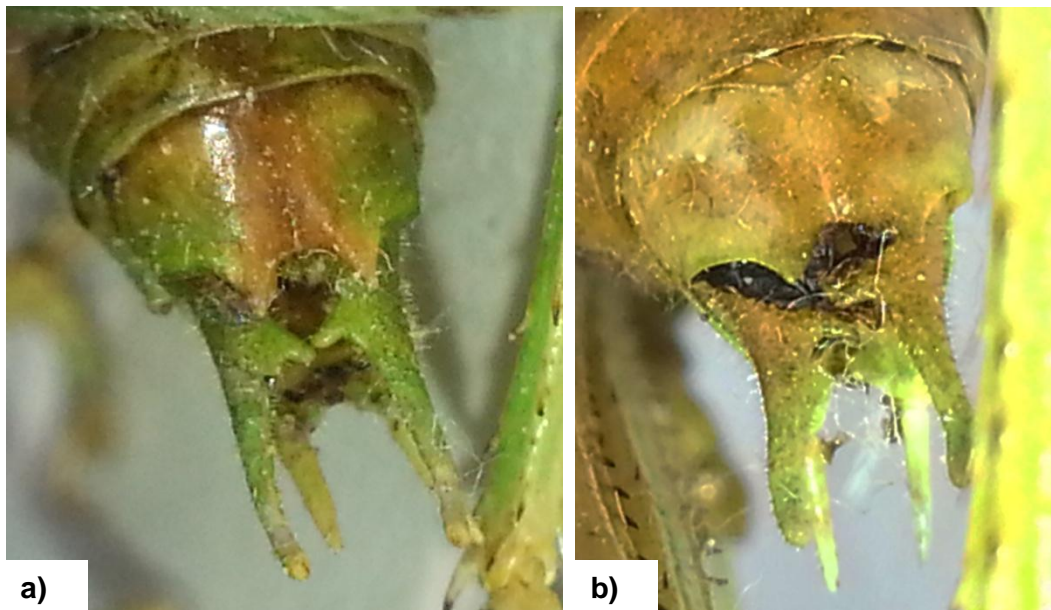


Fig. 8:
(a) Cerci of *Tettigonia viridissima*.
(b) Cerci of *Tettigonia dolichoptera*.
(c) Cerci of *Tettigonia orientails*
(STOROZHENKO 1994);



Fig. 9:
Subgenital plate of
(a) *Tettigonia viridissima*
(b) *Tettigonia dolichoptera*.

Discussion

Although *T. viridissima* is not distributed in the eastern most part of the Eurasian continent, it has been notified to live in the North Pacific Coast of the continent for a long time. Its range seems to be limited in the East to the Altai Mts. (STOROZHENKO 1994) and Xinjang (Western China at the border between Kazakhstan and China – Tian-Shan; JIN & XIA 1994). The wing morphology of the two species *T. viridissima* and *T. dolichoptera* is similar, however, the species are distinguished clearly by the form of the tegmina and the form of the cerci. According to SCHUL (1998) females of *T. viridissima* will not be attracted to the song of *T. cantans* (Fuessely, 1775) which has a song similar to that of *T. dolichoptera*, because they need long sound pulses and large intervals. Obviously they combine both syllables of a syllable pair to one sound unit (see Fig. 7 in SCHUL 1998). Females of *T. cantans*, however, use syllable rate for song recognition. In Japan, there are several, partly undescribed *Tettigonia* species with differing song patterns (ICHIKAWA et al. 2006). Probably SCHUL's (1998) work will give an idea how to identify species of the *Tettigonia orientalis* complex in Japan.

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