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Araştırma Makalesi / Research Article

Color/ Pattern Variation of *Cercopis vulnerata* Rossi, 1807 (Auchenorrhyncha: Cercopidae) Populations of Northwestern Turkey

Rukiye TANYERİ[1*], Ünal ZEYBEKOĞLU[2]

Abstract

This study was carried out to examine color/pattern variation in some *C. vulnerata* populations in northwestern of Turkey. Three different phenotypes were recognized according to wing color/pattern, two of which are *C. vulnerata* var. *typica* and *C. vulnerata* var. *helvetica*. The third phenotype has a different pattern from all known variants of this species. The data about the color/pattern variation of *C. vulnerata* were examined for the first time in Turkey with this study. Besides color/pattern differences, size differences were examined. The samples were classified according to their color/pattern differences and also the total length of the individuals were measured. In order to assure whether the differences are statistically significant among the variants and between sexes, One-Way ANOVA and independent t-test were used. Differences in body size among all variants were significant ($P < 0.01$). The populations of *C. vulnerata* var. *helvetica* are overwhelmed in the region. In this variant, it was also found that there was a sexual dimorphism in size, and male individuals were larger than females. This feature was significant (♀♀ n = 50, ♂♂ n = 50, $P < 0.01$). In the other variants, no significant difference was found between the sexes.

Keywords: *Cercopis vulnerata*, variant, Turkey, color morphs.

Cercopis vulnerata Rossi, 1807 (Auchenorrhyncha: Cercopidae)'nın Kuzeybatı Türkiye Populasyonlarındaki Renk/Desen Varyasyonu

Öz

Bu çalışma Türkiye'nin kuzeybatısındaki bazı *C. vulnerata* populasyonlarındaki renk/desen varyasyonunu incelemek amacıyla yapılmıştır. Kanatlardaki renk/desen varyasyonuna göre 3 farklı fenotip tespit edilmiştir. Tespit edilen fenotiplerden ikisi *C. vulnerata* var. *typica* and *C. vulnerata* var. *helvetica*'dır. Üçüncü fenotip ise türün bilinen tüm varyantlarından farklıdır. Bu çalışmayla *C. vulnerata*'nın gösterdiği renk/desen varyasyonu Türkiye'de ilk kez değerlendirilmiştir. Renk/desen varyasyonunun yanısıra boyut farklılıkları da değerlendirilmiştir. Örnekler renk/desen varyasyonuna göre gruplandırılmış ve total boyları ölçülmüştür. Varyantlar ve eşeyler arasındaki farklılıkların istatistiksel olarak önemli olup olmadığının saptanması için One-Way ANOVA ve Bağımsız T-test kullanılmıştır. Varyantlar arasındaki vücut boyutundaki fark istatistiksel olarak önemlidir ($P < 0.01$). Bölgede, *C. vulnerata* var. *helvetica*'nın baskın olduğu tespit edilmiştir. Bu varyantta ayrıca eşeysel boyut dimorfizmi tespit edilmiştir, erkekler dişilerden daha büyük boyutludur. Bu özellik istatistiksel olarak anlamlıdır (♀♀ n = 50, ♂♂ n = 50, $P < 0.01$). Diğer varyantlarda eşeyler arasında anlamlı bir boyut farkı yoktur.

Anahtar Kelimeler: *Cercopis vulnerata*, varyant, Türkiye, renk morfları.

[1]Sinop University, Faculty of Arts and Science Department of Biology, Sinop, Turkey, rtanyeri@sinop.edu.tr
[2]Ondokuz Mayıs University, Faculty of Arts and Science Department of Biology, Samsun, Turkey, unalz@omu.edu.tr

[1]https://orcid.org/0000-0001-9994-8763 [2]https://orcid.org/0000-0003-1646-5999

[*]**Sorumlu Yazar/Corresponding Author**
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1. Introduction

Cercopidae (Cercopoidea, Auchenorrhyncha, Cicadomorpha) is a xylem-sap sucking insect family. This family is characterized by their bright color patterns. Adults of this family can jump well, and their nymphs often produce a frothy secretion. Due to these features, they are known as froghoppers and spittlebugs (Carvalho et al., 2006). Their host plants range from wet grasses to trees. While their larvae may feed on plant roots the adults fed on aerial portion of plants. The members of this family are also known for causing severe damage to both natural and planted forest trees as well as orchards in Mexico, Italy and Spain (Castro-Valderrama et al., 2017). Adults can be observed in thermally favored lowlands at the end of April. They suck on various herbs and grasses in various open habitats such as extensively used meadows, pastures, fallow land, ruderal tracts, forest, roads and roadsides (Holzinger, 2008).

Known by its red-black coloration, the froghopper or spittlebug *C. vulnerata* exhibits phenotypic variation in color and pattern. This pattern is seen typically as red spots on the basal half of clavus and in the middle of corium, red stripes in posterior. *C. vulnerata* is different from the other species with its posterior red band on the fore wing, shaped as a wide 'V' and also genital structures (Holzinger et al., 2003). In males, the anterior pair of processes on the apex of the aedeagus is two thirds the length of posterior pair. The genital structures of *C. vulnerata* can be seen in Fig.1.

Four different variants of *C. vulnerata* have been described up to now based on forewing color/pattern. These are *C. vulnerata* var. *helvetica*, *C. vulnerata* var. *typica*, *C.vulnerata* var. *nicolausi* and. *C. vulnerata* var. *confluens* (Holzinger, 2008). On the pattern of fore wing of var. *typica,* there are spots on the clavus and corium which do not touch each other; also there is a subapical red band. In var. *confluens* there are spots on both the clavus and corium, and the subapical red bands are united (Heller, 1985). In *C. vulnerata* var. *helvetica* Melichar, 1896, the red spot on the clavus reaches to the scutellum point so that the middle red spot on the clavus seems to be in contact with it. Also, the horseshoe-shaped transverse band is wider than in the *typica* form (Melichar, 1896; Nast, 1933). In *C. vulnerata* var. *nicolausi* Wagner, 1948 the red spot on the corium and the transverse band are united (Wagner, 1948; Holzinger, 2008). In addition, Gibson (1976), described a new form of *C. vulnerata* with grey-brown and black markings instead of the usual red and black.

Cercopis vulnerata which is a mesophilic open-land species according to Nickel (2003) lives in locations that vary from moderately dry to moderately wet, and from sunny to partially shaded, in grasslands, pastures, forest clearings, and sparse forests (Holzinger et al., 2003) Meadows are rarely populated. Adults are polyphagous. They are found on grasses and high-growing herbs (*Solidago*, *Lupinus*, *Chrysanthemum*). In Italy and Slovenia, the species occupies different habitats (Mauri 1982), and this taxon has been a pest of young spruce trees in Poland (Kosibowicz 1989). It is a

common to abundant species in Europe. It has a single annual generation. It is also known for damaging to fruit trees, especially apple and cherries (Alford, 2016).

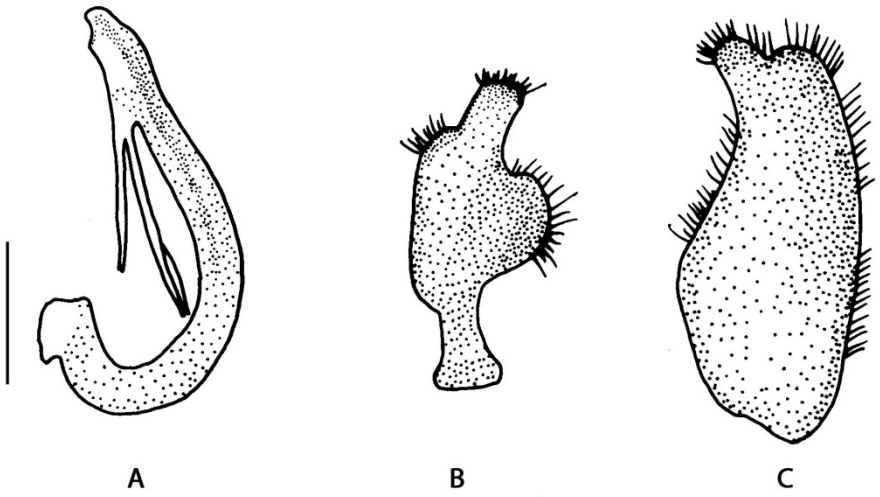

Figure 1. Genital structures of *Cercopis vulnerata* A, aedegus from lateral; B, stylus; C, genital plate (Scale: 0,5 mm)

2. Material and Methods

In this study, the material was collected from Sinop and Kastamonu provinces in the West-Black Sea region of Turkey. The rural areas which were studied were at different altitudes from 50 m to 1200 m. The study was carried out between early May 2016 and late June 2018. The sampling of the adults was implemented periodically every month. The spittlebugs were frequently collected from the herbaceous plants in humid habitats near water sources, such as mini-meadows, stream sides and roadsides. The localities are given in Table 1. In the sampling of the adults, a standard sweeping net and a hand- held aspirator were used. Each sampling process took nearly one hour. The specimens were examined in the laboratory by using a binocular stereomicroscope. All of the individulas were prepared by standard insect preparation and were identified according to (Dusolier, 2004; Holzinger, 2008).

An overview photograph of dry samples was taken with Canon EOS 70D model camera connected to Zeiss Stem 2000-C stereomicroscope. The shapes of genital structures were drawn using Zeiss discovery V-20 stereomicroscope attached drawing attachment.

Furthermore, size differences were also observed in the field studies. Thus the dry samples were separated according to color/pattern differences, and the length of the individuals was measured. In order to assess whether the differences between variants (30 ♂♂, 30♀♀) and sexes were statistically significant, one-Way ANOVA and independent t-test were used.

Table 1. Coordinates of localities and specimen numbers of *C. vulnerata*.

Locality		Date	Coordinates	Habitat	Specimens
1	Kastamonu	19/05/2017	41° 42' 04.3" 33° 30' 04.5"	Open area in the forest	10 ♂♂, 20 ♀♀
2	Kastamonu	19/05/2017	41° 42' 08.7" 33° 28' 56.3"	Open area in the forest	8 ♂♂, 12 ♀♀
3	Kastamonu	19/05/2017	41° 42' 08.4" 33° 26' 37.0"	Hilly meadow	30 ♂♂, 35 ♀♀
4	Kastamonu	19/05/2017	41° 37' 55.4" 33° 15' 53.5"	Grassland	40 ♂♂, 45 ♀♀
5	Kastamonu	20/05/2017	41° 52' 48.9" 33° 42' 38.0"	Hilly meadow	30 ♂♂, 25 ♀♀
6	Kastamonu	20/05/2017	41° 58' 25.00" 33° 48' 27.9"	Open area in the forest	66 ♂♂, 36 ♀♀
7	Kastamonu	20/05/2017	41° 55' 31.9" 34° 10' 56.2"	Fruit trees	21 ♂♂, 34 ♀♀
8	Sinop	27/05/2017	41° 49' 12.2" 35° 03' 54.7"	Open area, grassland	16 ♂♂, 12 ♀♀
9	Sinop	27/05/2017	41° 44' 52.0" 34° 57' 40.9"	Open area, grassland	18 ♂♂, 16 ♀♀
10	Sinop	27/05/2017	41° 32' 45.1" 34° 47' 0.01"	Open area, grassland	12 ♂♂, 14 ♀♀
11	Sinop	13/06/2017	41° 45' 40.7" 34° 58' 32.4"	Open area in the forest	8 ♂♂, 12 ♀♀
12	Sinop	13/06/2017	41° 35' 17.4" 34° 51' 01.3"	Open area in the forest	11 ♂♂, 12 ♀♀
13	Sinop	13/06/2017	41° 35' 50.1" 34° 51' 04.6"	Open area in the forest	24 ♂♂, 22 ♀♀
14	Kastamonu	14/06/2017	41° 05' 58.5" 34° 02' 59.5"	Riverside, open area	28 ♂♂, 32 ♀♀
15	Kastamonu	14/06/2017	41° 14' 03.9" 34° 00' 45.6"	Grassland	12 ♂♂, 14 ♀♀
16	Kastamonu	14/06/2017	41° 15' 12.2" 33° 59' 53.8"	Riverside, open area	28 ♂♂, 30♀♀

3. Results

A total of 374 ♂♂ and 371 ♀♀ specimens were collected from 16 localities in northwestern Turkey. All of the specimens were classified according to their color/pattern differences. In this study, three different variants of *C. vulnerata* were identified (Fig. 2). Two of these are *C. vulnerata* var. *typica* and *C. vulnerata* var. *helvetica* but no information was obtained about the third form. This third form is thought to be a new variant, having a red spot in the middle of the corium which reaches to the clavus and posterior red band. It has a different pattern on the fore wing from the other mentioned variants. It seems similar to var. *confluens* but it differs with having black spots on the upper parts of clavus and corium. Polymorphism is not limited to sex; the female and male specimens show the same color/pattern, but the small black spot on the lower part of the corium is larger in males.

The largest size belongs to *C. vulnerata* var. *helvetica* among the variants and the differences in size are significant (P <0.01) among all forms. The mean body size was determined as 9,18 mm in var. *typica*, 10,3 mm in var. *helvetica* and 9,78 mm in the new variant. The populations of *C. vulnerata* var. *helvetica* are dominant in the region. In this variant, it was also found that there was a sexual dimorphism in size, and male individuals were larger than females. This feature was significant (♀♀ n = 50, ♂♂ n = 50, P <0.01). In the other variants, no significant difference was found between the sexes. *Typica* and *helvetica* were found in all sampling areas. The third variant has been seen for the first time in this study and it can be considered as a new variant which is commonly seen in some localities where apple trees and roses are abundant (Locality 7 and12).

Figure 2. *Cercopis vulnerata* dorsal view A, *C. vulnerata* var. *typica*; B, *C. vulnerata* var. *helvetica*; C, new phenotype) (Scale: 1 mm)

4. Discussion and Conclusion

C. vulnerata occurs in central and southern Europe as well as Turkey (Nast, 1987; Lodos and Kalkandelen, 1981; Önder et al., 2011). In the Mediterranean it is limited to higher and cooler locations. No studies have been carried out on the phenotypic variation of *C. vulnerata*, which has a limited number of local records in Turkey. The phenotypic variation of *C. vulnerata* in Turkey was evaluated for the first time with this work. Holzinger (2008), described four different variants of *C. vulnerata* on forewing color/pattern (*C. vulnerata* var. *helvetica*, *C. vulnerata* var. *typica*, *C.*

vulnerata var. *nicolausi* and. *C. vulnerata* var. *confluens*). Of these variants three were reported from Turkey except *C. vulnerata* var. *nicolausi* in this study. In addition, a new variant has been identified that differs from all known variants.

Many insects have spectacularly patterned wings (including beetles and dragonflies, butterflies and moths, over 100 000 species), and studying these colors and patterns in nature has been a popular field of research (Parchem et al., 2007). Color variation is common in mammals, fish, amphibians, reptiles, birds and some invertebrate taxa (e.g. land snails, spiders and butterflies). It affects the evolutionary dynamics and ecological success of species and populations. It has been seen that body coloration has strong consequences in predator avoidance, thermoregulation, reproductive strategies, microhabitat utilization, developmental stability, mate choice and speciation. Hypotheses explaining the evolution of color polymorphism are often based on the assumption that color morphs are genetically determined, but the phenotype of organisms may also be influenced by environmental cues experienced during ontogeny (Hochkirch et al., 2008). When these color polymorphisms are supported by genomic and ecological data, the study of microevolutionary forces that cause of genetic variation is considered to be an excellent system for determining speciation and adaptation (Rodrigues et al., 2016). Understanding the generation of phenotypic variation is an important challenge for modern evolutionary biology (Beldade et al, 2005). Additionally, wing color patterns are important in sexual selection, mimicry, and predator avoidance, and these functions have been the topic of several studies.

The genetic basis of phenotypic traits in polymorphic systems is often simple and depends on a few loci (Svensson and Abbott, 2005). The meadow spittlebug, *Philaenus spumarius*, is assumed to have a single pigmentation locus and seven alleles acting on the variation of more than 11 phenotypes (Halkka and Halkka, 1990). Also, body coloration is influenced by environmental factors such as temperature, humidity, color of the substrate on which the nymphs are reared, latitude, climatic variables and habitat type. Both genetic and environmental determination of color polymorphism have been found in insects as a combination of both. For example the coloration of pygmy grasshoppers is not only determined genetically, but also influenced by the environment (Hochkirch et al., 2008; Yadav et al., 2018). However there is no data on the factors that shape phenotypic variation of *C. vulnerata*.

Body size is a key feature of the organisms and varies continuously due to the effects of natural selection (Chown and Gaston, 2010). Intraspecific and interspecific body size frequency has played important roles in the developments of macroecology. There is much information about interspecific body size frequency distributions in vertebrates and insects from a macroecological perspective. On the other hand, despite the fact that intraspecific body size frequency distributions constitute a central component of macroecology, physiological and ecological interactions have not been widely

documented in insects. In conclusion, it seems that body size variation occurred in the variants of *C. vulnerata* can be an example for these studies.

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References

Alford, D. V. (2016). *Pests of fruit crops: a color handbook* (Second Edition). ABD: CRC press.

Beldade, P., Brakefield, P. M. and Long, A.D. (2005). Generating phenotypic variation: prospects from ''evo-devo'' research on *Bicyclus anynana* wing pattern. *Evolution & Development*, 7:2, 101-107.

Carvalho, G. S. and Webb, M. D. (2006). Cercopid Spittle Bugs of the New World (Hemiptera, Auchenorrhyncha, Cercopidae. *Annals of the Entomological Society of America*, 99:6, 1259–1260.

Castro-Valderrama, U., Romero-Nápoles, J., Peck, D. C., Valdez-Carrasco, J. M., Llanderal-Cázares C., Bravo-Mojica H. & Cibrián-Llanderal V. D. (2017). First report of spittlebug species (Hemiptera: Cercopidae) associated with *Pinus* species (Pinaceae) in Mexico. *Florida Entomologist*, 100(1): 206-208.

Chown, S.L. & Gaston, K.J. (2010). Body size variations in insects: a macroecological perspective. *Biological Reviews*, 85: 139-169.

Dusolier, F. (2004). Hemipteres nouveaux ou rares pou le Massif Armorican (Hexapoda, Hemiptera). *Bulletin de Societe des Sciences Naturelles Quest de la France*, 26: 128-137.

Gibson, D. O., 1976. A new form of *Cercopis* vulnerata II1. (Hem. Horn. Cicadoidia). *Entomologist's Record and Journal of Variation*, 88: 261.

Halkka, O. & Halkka, L. (1990).Population genetics of the polymorphic meadow spittlebug, *Philaenus spumarius* (L.). *Evolutionary Biology*, 24: 149–191.

Heller, F. (1985). *Cercopis vulnerata* (Rossi) var. *confluens* var. *nova* (Homoptera, Cercopidae). *Mitteilungen des Entomologischen Vereins Stuttgart 1869 e.V*, 20: 16-18.

Hochkirch, A., Deppermann, J. & Gröning J. (2008). Phenotypic plasticity in insects: the effects of substrate color on thecoloration of two ground-hopper species. *Evolution & Development*, 10(3): 350-359.

Holzinger, W. E., Kammerlander I. & Nickel H. (2003). *The Auchenorrhyncha of Central Europe. Fulgoromorpha, Cicadomorpha excl. Cicadellidae.* Koninklijke Brill NV.

Holzinger, W.E. (2008). Die Gemeine Blutzikade (*Cercopis vulnerata*) das Insekt des Jahres 2009 (Hemiptera: Auchenorrhyncha: Cercopidae). *Beitrage zur Entomofaunistik*, 8: 193-203.

Lodos, N. & Kalkandelen A. (1981).Preliminary list of Auchenorrhyncha with notes on distribution and importance of species in Turkey VI. Families Cercopidae and Membracidae. *Türkiye Bitki Koruma Dergisi*, 5 (3): 133-149.

Melichar, L. (1896). Einige neue Homoptera-Arten und Varietäten. *Verhandlungen der Zoologisch-Botanischen Gesellschaft Wien*, 46: 176-180.

Nast, J. (1933). Beiträge zur Morphologie und geographischen Verbreitung der mitteleuropäischen und mediterranen Arten aus der Subfamilie Cercopinae (Homoptera, Cercopidae). *Annales Musei Zoologici Polonici*, 10 (2): 7-33.

Nast, J. (1987).The Auchenorrhyncha (Homoptera) of Europe. *Annales Zoologici Warszawa*, 40/15: 535–661.

Nickel, H. (2003). The Leafhoppers and Planthoppers of Germany (Hemiptera Auchenorrhyncha): Patterns and strategies in a highly diverse group of phytophageous insects. *Deutshe Entomologische Zeitschrift Banner***,** 50: 259-260

Önder F., Tezcan S., Karsavuran Y. ve Zeybekoğlu Ü. (2011). *Türkiye Cicadomorpha, Fulgoromorpha ve Sternorrhyncha Kataloğu*. Meta Basım, İzmir.

Parchem, R.J., Perry, M. W. & Patel, N.H. (2007). Patterns on the inseect wing. *Current Opinion in Genetics and Development*, 17: 300-308.

Rodrigues, A. S., Silva, S. E., Pina-Martins, F., Loureiro, J., Castro, M., Gharbi, K., ... & Jiggins, C. D. (2016).Assessing genotype-phenotype associations in three dorsal colour morphs in the meadow spittlebug *Philaenus spumarius* (L.)(Hemiptera: Aphrophoridae) using genomic and transcriptomic resources. *BMC genetics***,** 17(1), 144.

Svensson, E.I. & Abbott, J. (2005). Evolutionary Dynamics and population biology of a polymorphic insect. *Journal of Evolutionary Biology*, 18: 1503-1514.

Wagner, W. (1948). Neue deutsche Homopteren und Bemerkungen über schon bekannte Arten. *Verhandlungen des Vereins für naturwissenschaftliche Heimatforschung Hamburg*, 29: 72-89.

Yadav, S., Stow, A. J., Harris R. & Dudaniec, R. Y. (2018)**.** Morphological variation tracks environmental gradients in an agricultural pest, *Phaulacridium vittatum* (Orthoptera: Acrididae). *Journal of Insect Science*, 18 (6): 13; 1-10.