Exp Appl Acarol (2015) 67:457–466
DOI 10.1007/s10493-015-9948-6

External morphological anomalies in ixodid ticks from Thrace, Turkey

Sirri Kar[1] · Gurkan Akyildiz[1] · Nadim Yilmazer[1] · Taher Shaibi[2] · Aysen Gargili[3] · Zati Vatansever[4]

Received: 9 April 2015 / Accepted: 10 July 2015 / Published online: 12 August 2015

Abstract Of 18,667 ticks examined, 33 specimens from species identified as *Haemaphysalis parva*, *Hyalomma marginatum*, *Hy. scupense*, *Rhipicephalus bursa* and *Rh. turanicus* were found to have external morphological anomalies. Anomalous *Ha. parva*, *Hy. scupence* and *Rh. turanicus* were reported in this study for the first time. General anomalies manifested as asymmetry and deformations of the idiosoma, whereas local anomalies occurred in legs, exoskeleton, spiracular, adanal, subanal and accessory plates, mouthparts and capitulum. With this study describing a gynandromorphic *Hy. marginatum*, the number of gynandromorphic tick cases has been raised to two in Turkey.

Keywords Ticks · Anomalies · *Haemaphysalis* · *Hyalomma* · *Rhipicephalus* · Thrace

Introduction

Described in many articles, morphological anomalies in ticks have been known since L.G. Neumann who was a professor at National Veterinary School of Toulouse, France, and was the first to publish some anomalous ixodid ticks in 1899, as reported by Feldman-Muhsam (1950). External morphological anomalies which are seen much more frequently in ixodid ticks are generally grouped in two categories: General and local anomalies. While the formerincludes asymmetry, and bifurcation of the idiosoma, dwarfism, gigantism and gynandromorphism, the latter is related tooligomely, atrophy (brachymely), symely, heterosymely, anisomely, schistomely, ectomely, ectromely, polymelyand heteromorphose (heteromorphosis) of legs, deformities of certain mouthparts, Haller's sensory organ and

✉ Sirri Kar
sirrikar@yahoo.com

1 Department of Biology, Namik Kemal University, Tekirdag, Turkey

2 Department of Zoology, Faculty of Science, Tripoli University, Tripoli, Libya

3 Faculty of Health Science, Marmara University, Istanbul, Turkey

4 Parasitology Department, Faculty of Veterinary Medicine, Kafkas University, Kars, Turkey

anus structure, oligomely of the porose area and chelicera, anomaly in the form and course of the anal groove (Campana-Rouget 1959; Haarløv 1962; Buczek et al. 1991, 2004 Buczek 1995; Leonovich and Belozerov 2004; Dergousoff and Chilton 2007; Nowak-Chmura 2012). However, anomalies in the structure of internal organs also can be seen in ticks (Laptev 1963; Latif et al. 1988). The anomalies of taxonomically important structures, especially in gnathosoma may lead to taxonomic errors, and most identification mistakes result from local anomalies (Buczek 2000). Therefore, knowledge of morphological anomalies, especially local anomalies in ticks can help taxonomists to determine the species affiliation of anomalous ticks (Buczek 1995). Additionally, anomalous ticks can be more efficient vectors of tick-borne pathogens; hence this situation should be taken into account in human cases of tick bites (Alekseev et al. 2007; Nowak-Chmura 2012). This study aims to report new cases of morphological anomalies found in both natural and laboratory populations of some ixodid tick species collected from Thrace, the European part of Turkey.

Materials and methods

The tick specimens examined were collected from Thrace, the European part of Turkey in 2013. A total of 18,667 tick specimens included 444 nymphs and 18,223 adults. The latter formed natural population of the present study. 178 *Hy. marginatum* adults (87 males and 91 females) were collected from the ground by flagging, thus all hungry. Of 114 *Rh. bursa* nymphs, 37 were collected from the ears of goats, while the rest of the specimens from cows by hand picking method. Engorged nymphs of *Hy. scupense* and *Rh. bursa* were reared in the laboratory at constant temperature of 25 °C and 80–85 % relative humidity (RH) for development into adults which formed laboratory population of this study.

All specimens were identified to species level, using taxonomic keys in Walker et al. (2003) and Estrada-Peña et al. (2004). External morphology of the specimens was examined, and anomalous individuals were photographed using a stereomicroscope (Leica EZ4 HD). In addition, some anomalies were studied in detail through scanning electron microscopy (SEM) (Quanta FEG 250).

The anomalies observed were classified as general anomalies and local anomalies depending on the extent of the anomalies and their location, as proposed by Nowak-Chmura (2012). In order to describe various types of leg anomalies, the terminology of Mąkol and Łaydanowicz (2006) and Buczek (2000) was followed in that the following terms were used: atrophy (brachymely) = shortening of appendages; heteromorphosis = deformation of appendage segments and joints; oligomely = complete absence of appendages.

The specimens with anomalies have been deposited in the tick collection, Department of Biology, Namik Kemal University in Tekirdag, Turkey.

Results

The tick material studied comprised five species in three genera: *Ha. parva*, *Hy. marginatum*, *Hy. scupense*, *Rh. bursa* and *Rh. turanicus*. Of 18,667 ticks examined, all in the adult stage, 33 specimens in five species were found to be anomalous (0.18 %). Table 1 presents frequency of anomalies based on both species and gender.

Table 1 Frequency of anomalies in tick species studied

Species	Number of examined specimens	Number of anomalous specimens	% anomalous specimens
Ha. parva	208 (90 F, 118 M)	2 F	0.962 F
Hy. marginatum	11,677 (3521 F, 8156 M)	9 (5 F, 3 M, 1 G)	0.077 (0.142 F, 0.037 M, 0.009 G)
Hy. scupense	2998 (1424 F, 1574 M)	10 (5 F, 5 M)	0.334 (0.351 F, 0.318 M)
Rh. bursa	847 (362 F, 485 M)	4 (2 F, 2 M)	0.472 (0.553 F, 0.412 M)
Rh. turanicus	2937 (1467 F, 1470 M)	8 (4 F, 4 M)	0.272 (0.273 F, 0.272 M)
Total	18,667 (6864 F, 11,803 M)	33 (18 F, 14 M, 1G))	0.177 (0.262 F, 0.119 M)

F female, *M* male, *G* gynandromorphic

In the laboratory population including 444 adults which were developed from the nymphs, three specimens displayed anomaly (0.68 %). Frequency of anomalies in natural populations of ticks was 0.17 %. Of 178 unfed *Hy. marginatum* adults, four specimens were anomalous (2.25 %).

General anomalies manifested as asymmetry and deformations of the idiosoma, whereas local anomalies occurred in legs, exoskeleton, spiracular, adanal, subanal and accessory plates, mouthparts and capitulum. All anomalies recognized and described are summarized in Table 2.

One *Hy. marginatum* displayed gynandromorphism, the presence of both male and female features within the same organism. This gynandromorphic specimen was characterized by male features in dorsal view, whereas it lacked exact adanal plates, subanal plate and accessory plate. Those plates were in the appearance of protuberances without sclerization. Furthermore, mouthparts of this specimen were turned ventrally from the basis capituli (Fig. 3).

Due to overlap of various general and local anomalies at the same time, a total of 48 anomalous characters were described in 33 anomalous specimens. Of these, 34 characters (70.8 %) were related to local anomalies, and the rest to general anomalies. Exoskeleton anomalies were predominant within local anomalies, followed in decreasing order by spiracular plate and leg anomalies (23.5 and 20.6 %, respectively). As to general anomalies, nine anomalies out of 14 manifested as asymmetry of the idiosoma (64.3 %).

Discussion

Several tick species have been reported to have anomalous morphological characteristics to date, including *Amblyomma cajennense* (Labruna et al. 2002), *A. flavomaculatum* (Nowak-Chmura 2012), *A. latum* (Nowak-Chmura 2012), *A. oblongoguttatum* (Labruna et al. 2000), *A. variegatum* (Latif et al. 1988), *Argas arboreus* (Belozerov et al. 2003), *A. persicus* (Buczek et al. 1991), *A. polonicus* (Siuda 1981), *A. radiatus* (Obenchain and Oliver 1972), *A. reflexus* (Buczek 1988, 1991, 1993; Buczek et al. 2004), *Boophilus annulatus* (Sakla et al. 1980; Caeiro and Simões 1990), *B. australis* and *B. decoloratus* (Nuttall 1914), *Dermacentor andersoni* (Dergousoff and Chilton 2007), *D. marginatus* (Caeiro and Simões 1990), *D. occidentalis* (Oliver and Delfin 1967), *D. reticulatus*

Table 2 Anomalies recognized in tick species studied

Species	No. and gender	Description of anomalies
Ha. parva	1 Female	Deformed scutum
	1 Female	Asymmetry of the idiosoma marked in the wrinkled rear
Hy. marginatum	1 Female	Asymmetry of the idiosoma marked by distortion on its left rear side lacking spiracular plates, anus being moved to left side and crinkled body surface
	1 Female	Atrophy of the first and second left and the third right legs
	1 Female	Atrophy of the fourth right leg
	1 Female	atrophy of the second right and the fourth left leg appendage segments of which are longer than their counterparts
	1 Female	Oligomely of the second and fourth left legs and atrophy of the third left leg (Fig. 1)
	1 Male	Asymmetry of the idiosoma lacking spiracular plate on left side, wrinkled and undulated consucutum (Fig. 2)
	1 Male	Deformations in the rear edge of the idiosoma
	1 Male	Oligomely of the third left leg and atrophy of the fourth left leg
	1 Gyn	Rudimentary plates on a wrinkled area and mouthparts turned ventrally from basis capituli (Fig. 3)
Hy. scupense	1 Female	atrophy of all legs, the first right leg strongly reduced and with deformed segments (Fig. 4)
	1 Female	Asymmetry of the idiosoma marked in the crinkled rear
	1 Female	Asymmetry of the idiosoma deformed in the rear
	1 Female	Asymmetry of the idiosoma and wrinkled scutum
	1 Female	Markedly wrinkled scutum
	1 Male	Rudimentary anal, adanal and postanal plates on the right side in which there is a second rudimentary spiracular plate next to the spiracular plate (Fig. 5)
	1 Male	Dented and deformed consucutum
	1 Male	Asymmetry of the idiosoma, and wrinkled and dented conscutum
	1 Male	Rudimentary palps (Fig. 6)
	1 Male	Deformed idiosoma
Rh. bursa	1 Female	Lack of capitulum, heteromorphose of the first three legs on both sides and atrophy of both fourth legs (Fig. 7)
	1 Female	Asymmetry of the idiosoma marked by an indentation on the left side at the level of the fourth leg
	1 Male	Asymmetry of the idiosoma, and deformed adanal plates
	1 Male	Distorted adanal plate
Rh. turanicus	1 Female	Deformation in the rear of scutum
	1 Female	Rudimentary spiracular plate
	1 Female 2 Males	Spiracular plate with bifurcated tail (Fig. 8)
	1 Female 2 Males	Spiracular plate with trifurcated tail

No. number of specimens, *Gyn* gynandromorphic

Fig. 1 *Hyalomma marginatum*, female, oligomely of the second and fourth left legs and atrophy of the third left leg

Fig. 2 *Hyalomma marginatum*, male, wrinkled and undulated consucutum and asymmetry of the idiosoma, lacking spiracular plate on left side

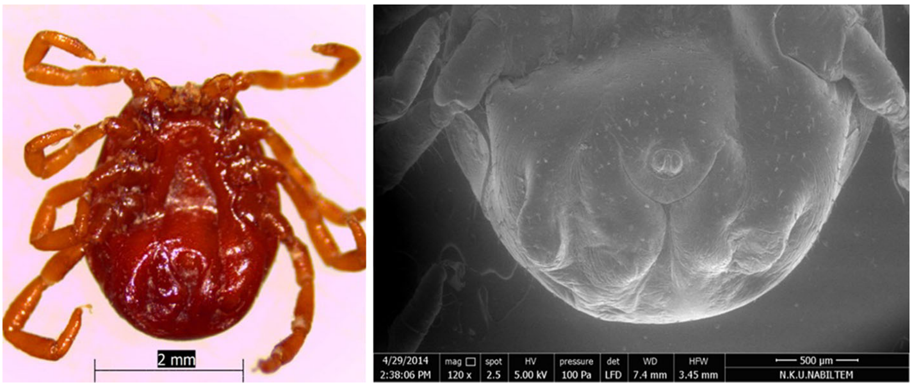

Fig. 3 Gynandromorphic *Hyalomma marginatum* with mouthparts turned ventrally from the basis capituli, and lacking exact adanal plates, subanal plate and accessory plate which were in the appearance of protuberances without sclerization

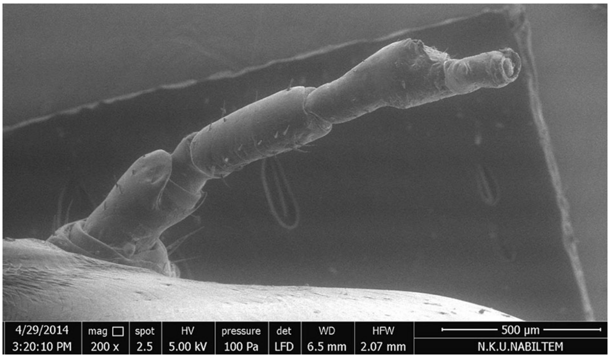

Fig. 4 *Hyalomma scupense*, female, strongly reduced first right leg with deformed segments

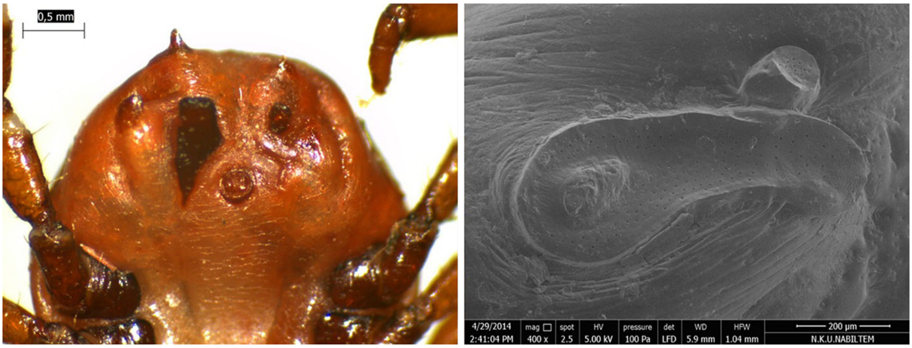

Fig. 5 *Hyalomma scupense*, male, rudimentary anal, adanal and postanal plates on the *right side* in which there is a second rudimentary spiracular plate next to the spiracular plate

Fig. 6 *Hyalomma scupense*, male with rudimentary palps

(Alekseev et al. 2008; Buczek et al. 2013), *Haemaphysalis neumanni* (Laptev 1963), *H. punctata* and *H. sulcata* (Tovornik 1987), *H. longicornis* and *H. turturis* (Belozerov and Leonovich 1995), *Hyalomma aegyptium* (Nuttall 1914; Nowak-Chmura 2012), *H. asiaticum* (Leonovich and Belozerov 2004), *H. lusitanicum* (Caeiro and Simões 1990), *H.*

Fig. 7 *Rhipicephalus bursa*, female lacking capitulum and with heteromorphose of the first three legs on both sides and with atrophy of both fourth legs

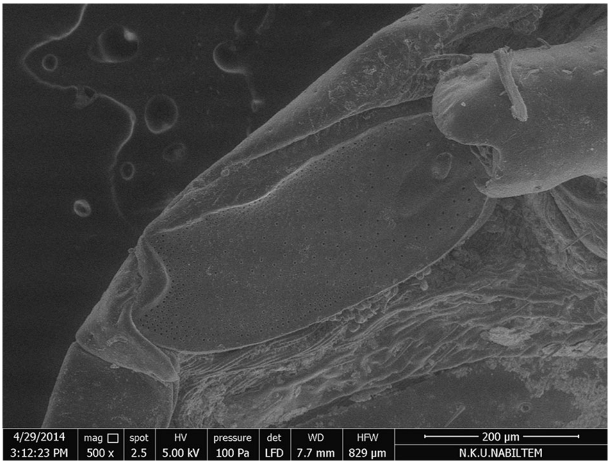

Fig. 8 Spiracular plate with bifurcated tail observed in one female and two males *Rhipicephalus turanicus*

marginatum (Caeiro and Simões 1990; Buczek et al. 1991; Buczek 2000; Buczek et al. 2004; Keskin et al. 2012), *H. savignyi* (Feldman-Muhsam 1950), *Ixodes arboricola* (Haarløv 1962), *I. hexagonus* (Tovornik 1987), *I. persulcatus* (Alekseev et al. 2000; Zharkov et al. 2000; Alekseev et al. 2007), *I. ricinus* (Tovornik 1987; Buczek et al. 1991; Zharkov et al. 2000; Belozerov 2003; Alekseev et al. 2008; Žygutienė et al. 2008), *I. scapularis* (Kittler 2011), *I. trianguliceps* (Tovornik 1987), *Ornithodorus moubata* (Robinson 1944), *Rhipicephalus bursa* (Caeiro and Simões 1990) and *R. sanguineus* (Nuttall 1914; Caeiro and Simões 1990; Estrada-Peña 2001; Labruna et al. 2002).

Anomalous *Ha. parva*, *Hy. scupence* and *Rh. turanicus* were reported in this study for the first time. However, morphological anomalies are not only seen in ticks, but also in mites (Madej et al. 2004; Mąkol and Łaydanowicz 2006) and some other arthropods including the beetle *Tenebrio molitor* (Balazuc 1948), the millipede *Glomeris marginata* (Juberthie-Jupeau 1969), the centipede *Stigmatogaster subterranean* (Leśniewska et al. 2009) and the spider *Tegenaria atrica* (Templin and Napiórkowska 2013).

Morphological anomalies which can be met at any developmental stage rarely occur in natural populations of ixodid ticks, with frequencies ranging from about 0.03 % to about 0.62 %. The percentage of anomalous specimens studied is concordant with the results of other researchers (Tovornik 1987; Latif et al. 1988; Buczek 1995; Guglielmone et al. 1999; Nowak-Chmura 2012). Environmental factors such as temperature, RH (Siuda 1981; Buczek 1988, 1991, 2000), pollution (Zharkov et al. 2000; Kittler 2011), and chemical agents including insecticides (Robinson 1944; Buczek et al. 2013), retinoic acid (Belozerov 2003, 2004), iodine compounds (Buczek 1993), sulfuric acid and ethyl quinone (Campana-Rouget 1959) were reported to lead to anomalies in both natural and experimental populations. Moreover, host resistance to tick infestation is known to change the morphology of subsequent tick development stages (Estrada-Peña 2001). Depending on pollution levels, ticks may exhibit higher rate of morphological anomalies (6–48 % of ticks in different populations) in polluted environments (Zharkov et al. 2000; Kittler 2011). Frequencies of anomalies observed in both natural and laboratory populations of this study are in accordance with the previous studies. Anomalies observed herein cannot be ascribed to an environmental factor such as pollution and/or chemical agents, since sampling areas were villages and their vicinity which are far away from industrial regions, and in which agriculture is restricted to basic needs, thus excluding pollution and pesticides as environmental factors responsible for anomalies. However, high temperature and RH can be effective causes, since sampling villages are hot (average temperature 27 °C) and receive high precipitation in summers, whereas winters are cold (average temperature 4 °C) and rainy (Gargili et al. 2010). Apart from environmental factors, genetic mutations, interspecies hybrids, regeneration after injury or damage to the body, density during parasitization of the host, parasitizing non-typical and accidental hosts, and lack of food are proposed as the reasons for the formation of anomalies in natural populations of ticks (Nowak-Chmura 2012).

In ixodid ticks, there are numerous reported cases of leg (Sakla et al. 1980; Tovornik 1987; Buczek et al.1991; Buczek 1995; Estrada-Peña 2001; Dergousoff and Chilton 2007; Nowak-Chmura 2012) and exoskeleton (Zharkov et al. 2000; Alekseev et al. 2007; Žygutienė et al. 2008; Kittler 2011) anomalies, and asymmetry of the idiosoma (Tovornik 1987; Latif et al. 1988; Buczek et al. 1991; Siuda et al. 2006; Nowak-Chmura 2012), while information on anomalies of spiracular, adanal, subanal and accessory plates, capitulum and mouthparts is rare. It is reported that abnormal embryonic development, adverse moulting conditions, injuries, abnormal regeneration and breeding under conditions of high humidity are the causes of leg anomalies in ticks, and in some cases these anomalies may be hereditary. On the other hand, the loss of legs, which causes the idiosoma to bend towards where there are no legs, loosening of the tissues and abnormal regeneration during metamorphosis from the immature stages to the adult, or the underdevelopment of the structures and organs in the idiosoma were suggested as the reasons for asymmetry of the idiosoma. Of the leading anomalies in this study, spiracular plate anomalies which may hinder the determination of the species and even the genus of a tick were also observed in many ticks of the genera *Hyalomma*, *Rhipicephalus* and *Amblyomma* (Nowak-Chmura 2012).

Gynandromorphism in ticks is an extraordinarily rare event in nature. To date, some 61 natural cases of gynandromorphic ticks have been reported from *Amblyomma* (17 cases), *Dermacentor* (2), *Haemaphysalis* (2), *Hyalomma* (21), *Ixodes* (5), and *Rhipicephalus* (14), the frequency of gynandromorphism in species of *Amblyomma* and *Hyalomma* being relatively higher in nature (Labruna et al. 2002; Keskin et al. 2012). Although various anomalies in ixodid ticks were documented in Turkey, one case of gynandromorphism has been reported in *Hy. marginatum* to date (Keskin et al. 2012). With this study, the number of gynandromorphic tick cases has been raised to two in Turkey.

References

Alekseev AN, Jensen PM, Dubinina HV, Smirnova LA, Makrouchina NA, Zharkov SD (2000) Peculiarities of behaviour of taiga (*Ixodes persulcatus*) and sheep (*Ixodes ricinus*) ticks (Acarina: Ixodidae) determined by different methods. Folia Parasitol 47:147–153

Alekseev AN, Dubinina HV, Jääskeläinen AE, Vapalahti O, Vaheri A (2007) First report on tick-borne pathogens and exoskeletal anomalies in *Ixodes persulcatus* Schulze (Acari: Ixodidae) collected in Kokkola coastal region, Finland. Int J Acarol 33:253–258

Alekseev AN, Dubinina HV, Zygutieni M, Efremova GA (2008) Ticks and other blood sucking arthropods as urban pests inside and outside dwellings. In: Robinson WH, Bajomi D (eds) Proceedings of the sixth international conference on urban pests, Printed by OOK-Press Kft., H-8200 Veszprém, Pápaiút 37/a, Hungary, pp 361–365

Balazuc J (1948) La tératologie des Coléopteresetexpériences de transplantation sur *Tenebrio molitor* L. Memoires du Museum National d'Histoire Naturelle Paris, n. S. 25:1–293

Belozerov VN (2003) Effect of juvenoids and retinoic acid on the development or larva and nymphs of the tick *Ixodes ricinus* L. (Acari: Ixodidae) and regeneration of Haller's organ during metamorphosis. Ontogenez 34(1):50–60

Belozerov VN (2004) Effect of methoprene and retinoic acid on characteristics of Haller's organ regeneration in the tick *Haemaphysalis longicornis* (Acari, Ixodidae). Ontogenez 35(3):213–219

Belozerov VN, Leonovich SA (1995) Pathways of regeneration of Haller's sensory organ during the life cycle of the tick *Hyalomma asiaticum*. J Exp Zool 271(3):196–204

Belozerov VN, Van Niekerk DJ, Butler HJB (2003) Population structure of *Argas arboreus* (Acari: Argasidae) ticks associated with seasonally abandoned mixed heronries, dominated by cattle egrets (*Bubulcus ibis*), in South Africa. Onderstepoort J Vet Res 70:325–330

Buczek A (1988) Studies on the biology of *Argas* (A.) *reflexus* (Fabricius, 1794) (Acari: Ixodida: Argasidae). I. Effect of temperature and relative humidity on embryonic development and egg hatch. Folia Biol 36:239–264

Buczek A (1991) Influence of high relative humidity on course of embryonic development and egg hatch of *Argas* (*A.*) *reflexus* (Fabricius, 1794) (Acari: Ixodida: Argasidae). Z Angew Zool 4:339–443

Buczek A (1993) Influence of iodine compounds on embryogenesis of *Argas* (*A.*) *reflexus* (Fabricius, 1794) (Acari: Ixodida: Argasidae). Acta Parasitol 38:41–43

Buczek A (1995) Teratological changes complicating taxonomical studies of ticks (Acari: Ixodida). Wiad Parazytol 41(3):289–304

Buczek A (2000) Experimental teratogeny in the tick *Hyalomma marginatum marginatum* (Acari: Ixodida: Ixodidae): effect of high humidity on embryonic development. J Med Entomol 37(6):807–814

Buczek A, Siuda K, Alsied S (1991) Morphological anomalies in ticks (Acari: Ixodidae) collected from nature. Wiad Parazytol 37:31–34

Buczek A, Stanisławek IM, Bartosik K, Kruk T, Olszewski T (2004) Local anomalies in ticks larvae (Acari: Ixodida). Wiad Parazyto 50(2):295–301

Buczek A, Bartosik K, Kuczyński P (2013) Evaluation of the effect of various concentrations of selected pyrethroids on the development of *Dermacentor reticulates* eggs and larvae. Ann Agric Environ Med 20(3):447–451

Caeiro VMP, Simões AJMDL (1990) Teratological phenomena in ticks in portugal. Revista Portuguesa De Ciencias Veterinarias 85(495):122–134

Campana-Rouget Y (1959) La tératologie des tiques. Ann Parasitol Hum Comp 34:209–260

Dergousoff SJ, Chilton NB (2007) Abnormal morphology of an adult Rocky Mountain wood tick, *Dermacentor andersoni* (Acari: Ixodidae). J Parasitol 93(3):708–709

Estrada-Peña A (2001) Abnormal development of *Rhipicephalus sanguineus* (Ixodidae). Exp Appl Acarol 25:757–761

Estrada-Peña A, Bouattour A, Camicas JL, Walker AR (2004) Ticks of domestic animals in the Mediterranean region. A guide of identification of species. University of Zaragoza Press, Zaragoza, p 131

Feldman-Muhsam B (1950) On some abnormalities in *Hyalomma savignyi*. Parasitology 40:93–95

Gargili A, Kar S, Yilmazer N, Cerit C, Sonmez G, Sahin F, Gunseli Alp H, Vatansever Z (2010) Evaluation of ticks biting humans in Thrace Province, Turkey. Kafkas Univ Vet Fak Derg 16(Suppl-A):141–146

Guglielmone AA, Castella J, Mangold AJ, Estrada-Peña A, Viñabal AE (1999) Phenotypic anomalies in a collection of Neotropical ticks Ixodidae. Acarologia 40(2):127–132

Haarløv N (1962) Variation in the ixodid tick, *Ixodes arboricola* Schulze & Schlottke 1929. Parasitology 52:425–439

Juberthie-Jupeau L (1969) Action tératogéne de la temperature surl'embryon de *Glomerismarginata* (Villers) (Myriapodes, Diplopodes). Memoires du Museum National d'Histoire Naturelle Paris 41(Suppl. 2):79–84

Keskin A, Bursali A, Tekin S (2012) A case of gynandromorphism in *Hyalomma marginatum* Koch, 1844 (Acari: Ixodidae). J Parasitol 98(6):1271–1272

Kittler RA (2011) The effects of heavy metal pollution on the morphology and behavior of the blacklegged tick (*Ixodes scapularis*) in the Northeastern United States. Senior Projects Spring 2011. Paper 313. http://digitalcommons.bard.edu/senproj_s2011/313

Labruna MB, Homem VSF, Heinemann MB, Neto JSF (2000) A case of gynandromorphism in *Amblyomma oblongoguttatum* (Acari: Ixodidae). J Med Entomol 37:777–779

Labruna MB, Riberio AF, Cruz MV, Camargo LM, Camargo EP (2002) Gynandromorphism in *Amblyomma cajennense* and *Rhipicephalus sanguineus* (Acari: Ixodidae). J Parasitol 88:810–811

Laptev VI (1963) Biology of *Haemaphysalis neumanni* Donitz, 1905 (Parthenogenesis). Trud Gos Inst Eksp Vet 28:129–136

Latif AA, Dhadialla TS, Newson RM (1988) Abnormal development of *Amblyomma variegatum* (Acarina: Ixodidae). J Med Entomol 25(2):142–143

Leonovich SA, Belozerov VN (2004) Regeneration of Haller's sensory organ in two species of hard ticks of the genus *Haemaphysalis* Acari: Ixodidae. Exp Appl Acarol 33(1/2):131–144

Leśniewska M, Bonato L, Fusco G (2009) Morphological anomalies in a Polish population of *Stigmatogaster subterranea* (Chilopoda: Geophilomorpha): a multi-year survey. Soil Organisms 81(3):347–358

Madej G, Karbowiak G, Buczek A (2004) Morphological anomaly in *Laelaps agilis* C. L. Koch, 1836 sensu Karg, 1971 (Mesostigmata, Acari) collected from nature. Stawonogi. In: Buczek A, Błaszak C (eds) Interakcjepasożyt-żywiciel, I edn. Liber, Lublin, pp 29–33

Mąkol J, Łaydanowicz J (2006) Morphological abnormalities in terrestrial Parasitengona mites (Acari: Actinotrichida). Biol Lett 43(2):131–143

Nowak-Chmura M (2012) Teratological changes in tick morphology in ticks feeding on exotic reptiles. J Natl Hist 46(15–16):911–921

Nuttall GHF (1914) Tick abnormalities. Parasitology 7(3):250–257

Obenchain FD, Oliver JH (1972) Abnormalities of leg regeneration in *Argas radiatus* (Acari: Argasidae). J Ga Entomol Soc 7(3):204–208

Oliver JH, Delfin ED (1967) Gynandromorphism in *Dermacentor occidentalis* (Acari: Ixodidae). Ann Entomol Soc Am 60(5):1119–1121

Robinson GG (1944) More cases of abnormal development in the Argasid tick, *Ornithodorus moubata* Murray. Parasitology 36(1–2):95–97

Sakla AA, Salit AM, Khalifa R (1980) Abnormal development in the tick *Boophilus annulatus* (Say, 1821) (Acarina, Ixodidae) in Assiut Province, Egypt. Acta Parasitol Pol 27(24):221–225

Siuda K (1981) Investigations on the biology of the tick *Argas* (*Argas*) *polonicus* Siuda, Hoogstraal, Clifford et Wassef, 1979 (Acarina: Ixodides: Argasidae). 3. Effect of temperature and relative humidity on embryonic development and egg hatch. Folia Biol 29:9–39

Siuda K, Nowak M, Kowalczyk M, Górz A, Piksa K, Szilman P, Karbowiak G (2006) Advances in polish acarology. In: Gabrýs G, Ignatowicz S (eds) Warszawa: SGGW: case of anomalies of ticks collected from natural environment (Acari: Ixodida: Ixodidae), pp 304–311

Templin J, Napiórkowska T (2013) Biometric studies on oligomelic individuals of the spider *Tegenaria atrica* (Arthropoda, Arachnida). Zool Pol 58:1–10

Tovornik D (1987) Teratological forms of ixodid ticks. Bioloski Vestnik 35:91–100

Walker AR, Bouattour A, Camicas JL, Estrada-Peña A, Horak IG, Latif AA, Pegram RG, Preston PM (2003) Ticks of domestic animals in Africa. A guide to identification of species. Bioscience Reports, Scotland

Zharkov SD, Dubinina HV, Alekseev AN, Jensen PM (2000) Anthropogenic pressure and changes in *Ixodes* tick populations in the Baltic region of Russia and Denmark. Acarina 8(2):137–141

Žygutienė M, Alekseev A, Dubinina H, Kazlauskienė R (2008) Evidence for a risk of tick-borne infection in the city parks of Vilnius, Lithuania. Ekologija 54(1):40–43