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Teratological deformities of pedipalps in the *Tegenaria atrica* spider, induced by low and high temperatures applied alternately

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ABSTRACT

The study was aimed at demonstrating the relationship between temperature (as a factor which disturbs morphogenesis) and deformities in the front part of the prosoma in *Tegenaria atrica*. By exposing spider embryos to alternating temperatures of 14 and 32 °C for the first 10 days of embryonic development, i.e. until the first metameres of the prosoma appeared on the germ band, we obtained individuals with a range of anomalies including those which affected the prosomal morphology. We selected five spiders with deformities of pedipalps or of pedipalps and walking legs for comprehensive analysis. The results indicate a relationship between temperature applied as a teratogenic factor and anomalies in the front part of the prosoma.

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1. Introduction

Morphological abnormalities are common in invertebrates collected from the natural environment. In arthropods, for example, exoskeleton and appendages are frequently malformed. So far, body malformations have been regularly observed in crustaceans (Fausto-Filho and de Costa, 1977; Fernandez et al., 2011; Feullassier et al., 2011; Follesa et al., 2008; Spanó et al., 2003), insects (Asiain and Márquez, 2009; Ferreira, 2011; Reinert, 1999) myriapoda (Leśniewska et al., 2009; Mitić and Makarov, 2007; Mitić et al., 2011) and arachnids (Ćurčić et al., 1983, 1991; Estrada-Peña, 2001; Kozel and Novak, 2013). However, morphological anomalies can also be induced under controlled laboratory conditions. A range of teratogenic factors including moisture (Buczek, 2000), selected chemical compounds (Buczek, 1992; Itow, 1979, 1980; Itow and Sekiguchi, 1979, 1980), and temperature (Jacuński, 1984; Jacuński et al., 2004; Juberthie, 1962, 1968; Napiórkowska et al., 2015) applied at various stages of embryonic development, lead to body deformities. The *Tegenaria atrica* spider is known to be sensitive to temperature. For this reason, the species has been frequently used for studies aimed at determining the impact of alternating temperatures applied in the early stages of embryogenesis (Jacuński et al., 2002a, 2002b; Napiórkowska and Templin, 2013; Napiórkowska et al., 2010a; Templin et al., 2009). Some abnormalities induced in laboratory are extremely rare and have a complicated structure. Affected individuals almost never reach sexual maturity because their biological processes, including molting, are impaired. In addition, increased mortality at various stages of development is observed among embryos exposed to this teratogen. Frequently, despite the successful completion of embryonic development, spiders are unable to leave eggs on their own, and even the researchers' attempt to help in the process are unsuccessful. Nevertheless, through numerous experiments we collected a group of *T. atrica* with morphological deformities, always related to changes in the internal systems, especially those with metameric structure.

We investigated modifications in the central nervous system of spiders affected by oligomely (absence of legs), heterosymely (fusion of legs lying next to each other on the same side of the prosoma), polymely (additional legs), bicephaly (presence of two heads), and so-called complex anomalies (a number of anomalies occurring simultaneously) (Jacuński and Napiórkowska, 2000; Jacuński and Templin, 1992; Jacuński et al., 2002a, 2002b, 2002c, 2005; Napiórkowska et al., 2010a, 2010b, 2013, 2015). Jacuński (1983) also analyzed changes in the digestive system.

The results indicate that malformations most commonly affect walking legs of spiders. Less frequent deformities are observed in the front part of the prosoma, affecting chelicerae and pedipalps. Several cases were described in the past (Jacuński, 2002; Jacuński et al., 2004; Napiórkowska et al., 2005). However, recent experiments using temperature as a teratogenic factor resulted in new

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cases of deformed mouth appendages. These were mainly pedipalp anomalies, which, owing to their unique characteristics, deserve further examination. The aim of this study was to show the relationship between temperature as a factor which disturbs morphogenesis and anomalies in the front of the prosoma of *T. atrica*.

2. Material and methods

The study involved specimens of *T. atrica* C. L. Koch (1843). During the late summer 2013 and 2014, we collected 79 sexually mature females and 33 males near the towns of Toruń and Chełmża (Poland). The spiders were transported to the laboratory and put into glass containers (capacity of 250 cm^3). They were kept in a dark room and provided with the conditions optimal for the species, i.e. the temperature of 21–23 °C and relative humidity of 70% (Jacuński et al., 1994; Mikulska and Jacuński, 1968). Both males and females were fed twice a week with larvae of *Tenebrio molitor* Linnaeus. Three weeks after the culture was established, a sexually mature male was introduced into the container with a female ready for fertilization. The first cocoons were laid at the beginning of November. Embryos removed from the cocoons were counted and divided into two groups: the control group, maintained in conditions optimal for the embryonic development of this spider species, and the experimental group exposed to temperatures of 14 and 32 °C applied alternately every 12 h. The procedure continued for ten days, until the first metameres of the prosoma appeared on the germ band. Subsequently, all experimental embryos were incubated under the same conditions as the control ones. Hatching took place approximately 20 days after the eggs were laid. All control and experimental larvae were evaluated for developmental deformities. Specimens with anomalies of the front part of the prosoma were placed in separate containers and photographed.

3. Results

During two breeding seasons we obtained approx. 2500 embryos, half of which constituted a control group. The mortality rate in the control group was around 6% but larvae which emerged from eggs did not have any developmental abnormalities. The mortality rate among experimental embryos was around 27%. 123 spiders in this group had various deformities of appendages and spinnerets (Table 1).

The most numerous group (79 spiders) consisted of individuals with deformities of walking legs: oligomely, schistomely, polymely, heterosymely, and symely. The second numerous group (23 spiders) consisted of individuals whose chelicerae and pedipalps were malformed. The least numerous group (10 spiders) consisted of individuals with anomalies of both pedipalps and walking legs (Table 2). In the second group as many as 15 spiders had pedipalp anomalies: 9 spiders lacked one pedipalp (right or left) and 6 were affected by schistomely. The remaining 8 spiders had chelicera anomalies. The third group included 10 spiders with so-called complex anomalies: malformations of pedipalps and walking legs occurred simultaneously. These spiders seem particularly interesting owing to the unique morphology and rare occurrence.

Of all three groups we selected 5 teratogenically modified spiders with different pedipalp deformities, which we then analyzed in detail.

Table 1
Observed cases of developmental anomalies in the prosoma and the opisthosoma in *Tegenaria atrica*.

Kind of anomaly	Number of individuals
Oligomely	79
Schistomely	12
Heterosymely	11
Polymely	9
Complex of anomalies	8
Bicephalous spiders	2
Symely	2
Total	123

Table 2
Cases and frequency of appendage anomalies in *Tegenaria atrica*.

Anomalies of appendages	Number of individuals	%
Walking legs	79	64
Feeding legs (pedipalps and chelicerae)	23	19
Feeding (pedipalps) and walking legs	10	8
Spinnerets	11	9
Total	123	100

3.1. Case 1

The spider shown in Fig. 1(A) (ventral side) is affected by oligomely: it lacks one pedipalp on the left side of the prosoma and walking legs on both sides. On the left side of the prosoma directly behind the chelicera (C), there are two properly formed walking legs (L_1, L_2), and on the right, behind the chelicera (C) and six-segmented pedipalp (P) with a well-developed gnathocoxa (G), there are three walking legs (L_1–L_3). They are properly built of seven segments. A severe oligomely of the appendages causes asymmetry of the prosoma and distorts the exoskeleton, carapace, and sternum.

3.2. Case 2

The spider shown in Fig. 1(B) (ventral side) has two pedipalps (P) but the left is teratogenically changed. It has a well-developed gnathocoxa (G) on the coxa but the remaining part is shorter and thicker compared to the pedipalp on the opposite side of the prosoma. The segmentation of this appendage is indistinct and the end is slightly bifurcated (light schistomely). The spider lacks two walking legs (L): one on the left, one on the right side of the prosoma, (bilateral oligomely).

3.3. Case 3

The spider in Fig. 1(C) (ventral side) is affected by three different anomalies: oligomely, heterosymely, and schistomely. It lacks one walking leg (L) on the left side of the prosoma (oligomely). On the right side of the prosoma a properly developed pedipalp (P) with a gnathocoxa (G) is partially fused with the first walking leg (L_1) (partial heterosymely). The anomaly affected only the first segments (coxae) of these appendages, completely different in terms of function and structure. In addition, the walking leg (L_1) fused with the pedipalp (P) is bifurcated (schistomely). In the distal part of this appendage two branches of equal length can be seen. They are formed in part by tibia, metatarsus and tarsus. The deformed walking leg is much thicker, especially the femur and patella while schistomelic (bifurcated) segments are of the same thickness as the segments of the remaining walking legs.

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