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Morphology and ultrastructure of *Tetranychus turkestani* Ugarov & Nikolskii (Acari: Tetranychidae)

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Abstract

Tetranychus turkestani is a serious pest of cotton, corn, vegetables, fruit trees and forests in Xinjiang. All life stages of *T. turkestani* were observed using both light and scanning electron microscope. The egg is smooth and spherical. The eupathidial spinnerets of larva and protonymph are different from that of the deutonymph and adult in shape. The spinneret of adult female is obviously thicker and larger than that in male. The palpfemoral seta of adult male is a short, stout, spine-like process. *T. turkestani* has fourteen pairs of dorsal setae. The number of ventral setae increases regularly in number in each molt. The leg chaetotaxy has a great change from larva to deutonymph.

Key words: Spider mite, adult, egg, larva, protonymph, deutonymph

Introduction

Tetranychus turkestani Ugarov et Nikolskii (Acari: Tetranychidae) is a serious pest on many plants, including cotton (*Gossypium hirsutum* L.), corn (*Zea mays* L.), sorghum (*Sorghum bicolor* L.), medlar (*Achras sapota* L.), tomato (*Lycopersicon esculentum* Mill.), bean (*Phaseolus vulgaris* L.), and other vegetables, fruit trees, and forest trees (Ugarov & Nikolskii 1937; Yu *et al.* 2000; Sohrabi & Shishehbor 2008; Guo *et al.* 2013; Zhang *et al.* 2016). It is mainly distributed in Russia, Kazakhstan, the United States, the Middle East and Xinjiang of China (Hill & Donnell 1991; Ros & Breeuwer 2007; Imani *et al*. 2009; Li *et al*. 2015). Previous research on *T. turkestani* focused on its biology and control (Yuan *et al*. 2008; Yang *et al*. 2012; Yang *et al*. 2013; Li *et al*. 2014; Duan *et al*. 2015; Liu *et al*. 2015). To our knowledge, its morphology has not been well studied, although all life stages of the mite have been simply described (Wang 1981; Lu 1990).

Morphological characters, such as the peritreme, aedeagus, tarsal claws and empodium, have often been used in identifying the species of Tetranychidae, and resolving the phylogenetic relationships between species (Gutierrez & Helle 1985; Lindquist 1985). Jeppson *et al*. (1975), Mollet & Sevacherian (1984) and Hong *et al*. (1994) studied the morphological characters and the density of the integumentary lobes and considered that the integumentary lobes were involved with thermal regulation. Some scholars have described the morphological characteristics of the mouthparts, setae and pedipalps, and inferred their functions from the morphology (Bostanian & Morrison 1973; Hislop & Jeppson 1976; Razaq *et al*. 2000).

The purpose of this study is to describe the morphological characteristics of all life stages of *T. turkestani* using light and scanning electron microscope, add ultrastructural details to the characteristics of *T. turkestani*.

Materials and Methods

Specimen preparation
The stock colony of *T. turkestani* was initiated from individuals collected from a cotton field near Huayuan, Shihezi City, Xinjiang Uygur Autonomous Region in 2010. This colony was maintained on potted sword bean (*Semen canavaliae* Gladiatae) in a growth chamber (FLI-2000H) at 26 ± 1 ºC, 60% RH, and a 16:8 h (L:D) photoperiod.

Light microscope
Mite eggs of different ages, 24 hr, 48 hr and 72 hr were photographed and measured using a stereo microscope (Zeiss Discovery V20). The post embryonic stages including larva, protonymph, deutonymph, and adult (female and male) were slide mounted, photographed and measured under a compound microscope (Olympus BX53).

Scanning electron microscope
The samples were fixed overnight in fixative (2.5% glutaraldehyde and 10% paraformaldehyde in 0.2 M phosphate buffer pH 7.2) at 4 ºC. The fixed samples were rinsed three times with the same buffer, and dehydrated in a graded series of acetone. Samples were then dried under natural conditions for 12 h. The dried samples were mounted on specimen stubs, coated with gold using ion sputter (E-1045), and observed under a scanning electron microscope (LEO 1430VP) at 20 kV and photographed.

Morphological measurements and statistical analyses
Body length and width, and idiosomal setal length were measured under the light microscope (LM) for 10 specimens, respectively. The data are presented as mean ± s.e. and analysed using SPSS 17.0 (SPSS, Chicago, IL).

Morphological terminology
Morphological terminology was adopted principally from Wang (1981), Lindquist (1985) and Hong (2012).

Results

Both sexes of *T. turkestani* have five stages, including egg, larva, protonymph, deutonymph and adult (Figs. 1A-1F).

Adult female (n=10)
Body oval in shape, 540.23 ± 3.40 µm long and 316.83 ± 5.03 µm wide (Figs. 2A, 2B), light-green to dark-green in color. Two E-shaped dark patches present on both sides of idiosoma (Fig. 1E).

Gnathosoma

Chelicera consist of a pair of whip-like stylet (*St*) (Fig. 2C) and a cystiform stylophore (*Sp*) (Figs. 2D, 3A). *Palpus* (*Pa*) (Fig. 3A) has 5 segments: trochanter (*Tr*), femur (*Fe*), genu (*Ge*), tibia (*Ti*) and tarsus (*Ta*) (Fig. 3B). Palpfemoral seta (*d*) is setiform (Fig. 3A), palptibial claw (*CI*) is well developed (Fig. 3D), palptarsus has striated cuticle and comprises seven smooth projections ($su\zeta$, ω, $ul'\zeta$, $ul''\zeta$, *a*, *b* and *c*) on its tip (Fig. 3D). Eupathidial spinneret ($su\zeta$) is cylindrical and its length is approximately two times as long as its width. Solenidion (ω) is peg-shaped. Eupathidia ($ul'\zeta$ and *ul″ζ*) are similar in form, elongate with a blunt apex. Three hair-like setae (*a*, *b*, *c*) are attenuate. *Subcapitulum* (*Sub*) bears a pair of subcapitular setae (*m*) (Fig. 3C). The apex of *rostrum* (*Ro*) is a large opening surrounded by soft flaps (Fig. 3C). *Peritremes* (*Pe*) are embedded in part of the membranous cuticle of stylophore. The last few segments of the peritreme are hooked (Fig. 2D).

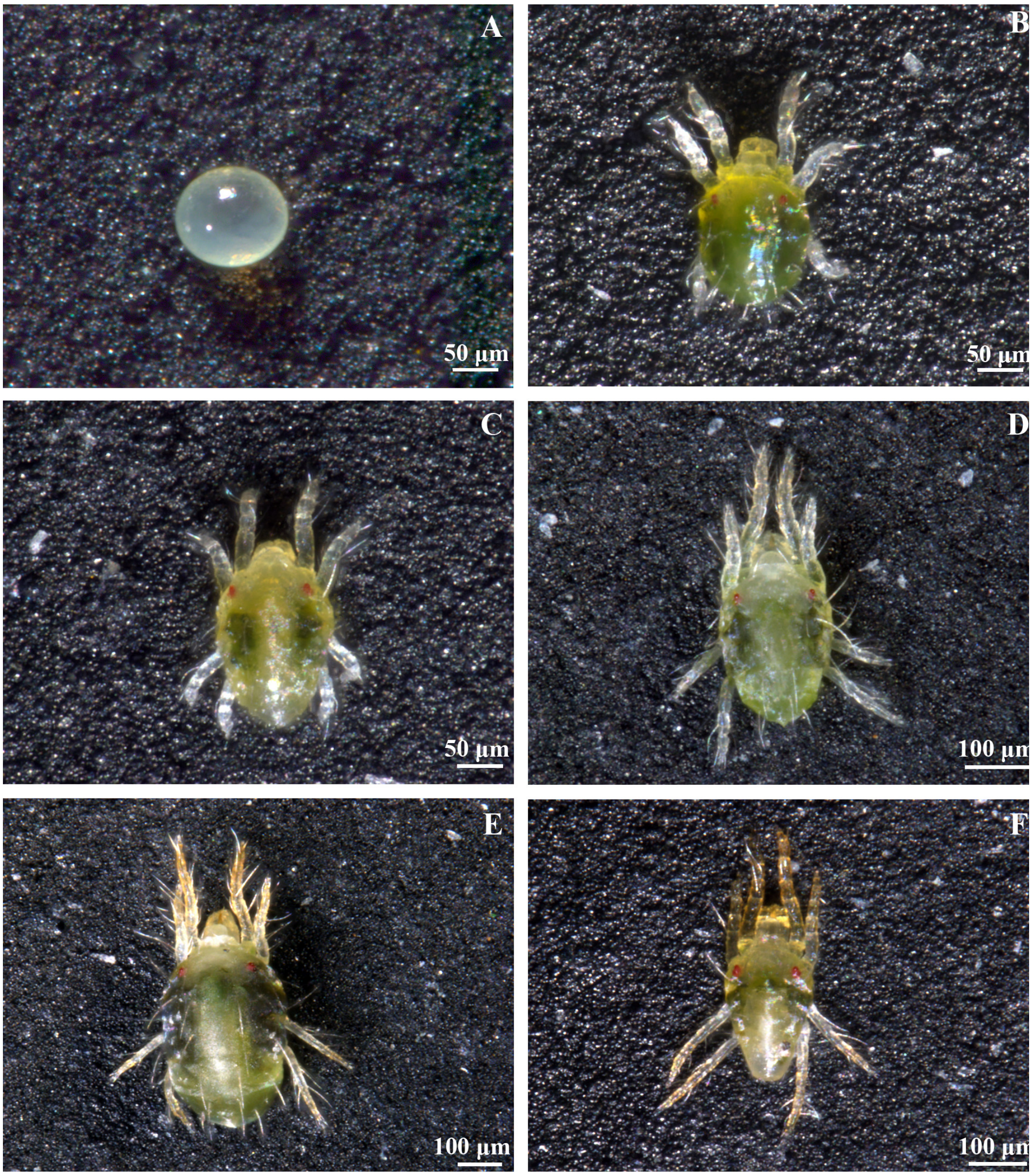

FIGURE 1. All stages of *Tetranychus turkestani* (LM). A, Egg; B, Larva; C, Protonymph; D, Deutonymph; E, Female adult; F, Male adult.

Idiosoma

Dorsum: Fourteen pairs of dorsal setae (v_2, sc_1, sc_2, c_1, c_2, c_3, d_1, d_2, e_1, e_2, f_1, f_2, h_2 and h_3) present (Figs. 2A, 3E). Eyes (*Eye*) on either side are consistently present between setae sc_1 and sc_2 surrounded by striated integument (Fig. 3A). The striae between the setae v_2 and sc_1 is semiorbicalar, and the integumentary lobes are semi-oblong (Fig. 4A). The striae between the setae c_1, d_1 and e_1 is transverse, and the integumentary lobes are semi-oblong or triangular (Figs. 4B, 4C). The striae between the seta e_1 is longitudinal and slanting, the integumentary lobes are semi-oblong (Fig. 4D). There is a diamond-shaped area between the setae e_1 and f_1, the integumentary lobes are semi-oblong or triangular (Fig. 4E). There are three lyrifissure (*Ly*) on the outside of the setae c_2, d_2 and e_2, and surrounded by semi-oblong integumentary lobes (Fig. 4F).

Venter: The chaetotaxy includes six pairs of coxisternal setae (*1b*, *1c*, *2b*, *2c*, *3b* and *4b*) (Fig. 2B), three pairs of intercoxal setae (*1a*, *3a* and *4a*) (Fig. 2B), one pair of aggenital setae (*ag*) (Figs. 2B, 3E), two pairs of genital setae (g_1 and g_2) and two pairs of pseudanal setae (ps_1 and ps_2) (Fig. 3E). The genital opening (*GO*) and anal opening (*AO*) are on the ventral side of the opisthosoma (Fig. 3E). The genital opening is transverse and surrounded by characteristically wrinkled membranous cuticle, and the Semi-circular shaped genital flap (*GF*) is in front of it (Fig. 3E). The striae of the genital flap is transverse, without integumentary lobes (Fig. 3F). The striae in the upper area of the genital flap is longitudinal and have a small number of granules (Fig. 3F).

Legs: Each leg includes coxa (*Cx*), trochanter (*Tr*), femur (*Fe*), genu (*Ge*), tibia (*Ti*), tarsus (*Ta*) and pretarsus (*Pr*) (Fig. 5A). There are nine tactile setae and one solenidion on tibia I (Fig. 5B). Two pairs of duplex setae (*ω'*, *ft'* and *ω"*, *ft"*) are found on the dorsum of tarsus I (Fig. 5C). The longer seta (*ω'* and *ω"*) is elongate and tapered, and the shorter seta (*ft'* and *ft"*) is barbed and apically forked. Tarsus I also has other kinds of setae, such as tectal setae (*tc'*), prorals (*p'ζ*) and primiventrals (*pv*) (Fig. 5D). The barbed tectal setae have well-developed sockets, while prorals and primiventrals are smooth. The empodium (*Em*) has three pairs of minute, attenuate hair-like processes (Fig. 5D). The claws of tarsus I are strongly reduced to two pairs of tenent hairs (*TH*) (Fig. 5D).

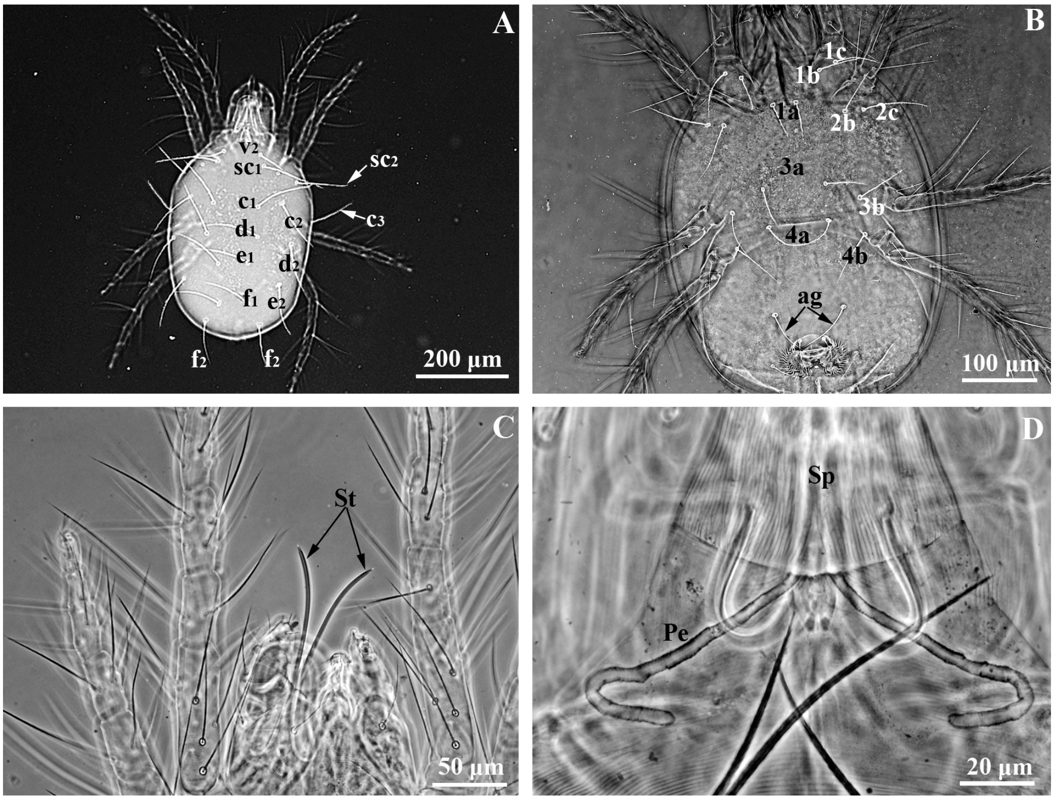

FIGURE 2. *Tetranychus turkestani* (adult female, LM). A, Dorsal view; B, Ventral view; C, Stylet (*St*) in ventral view; D, Peritreme (*Pe*) and stylophore (*Sp*) in dorsal view.

Adult male (*n*=10)

Body diamond-shaped, 412.10 ± 3.63 µm long and 192.53 ± 2.73 µm wide (Figs. 6A, 6B), light-green in colour (Fig. 1F).

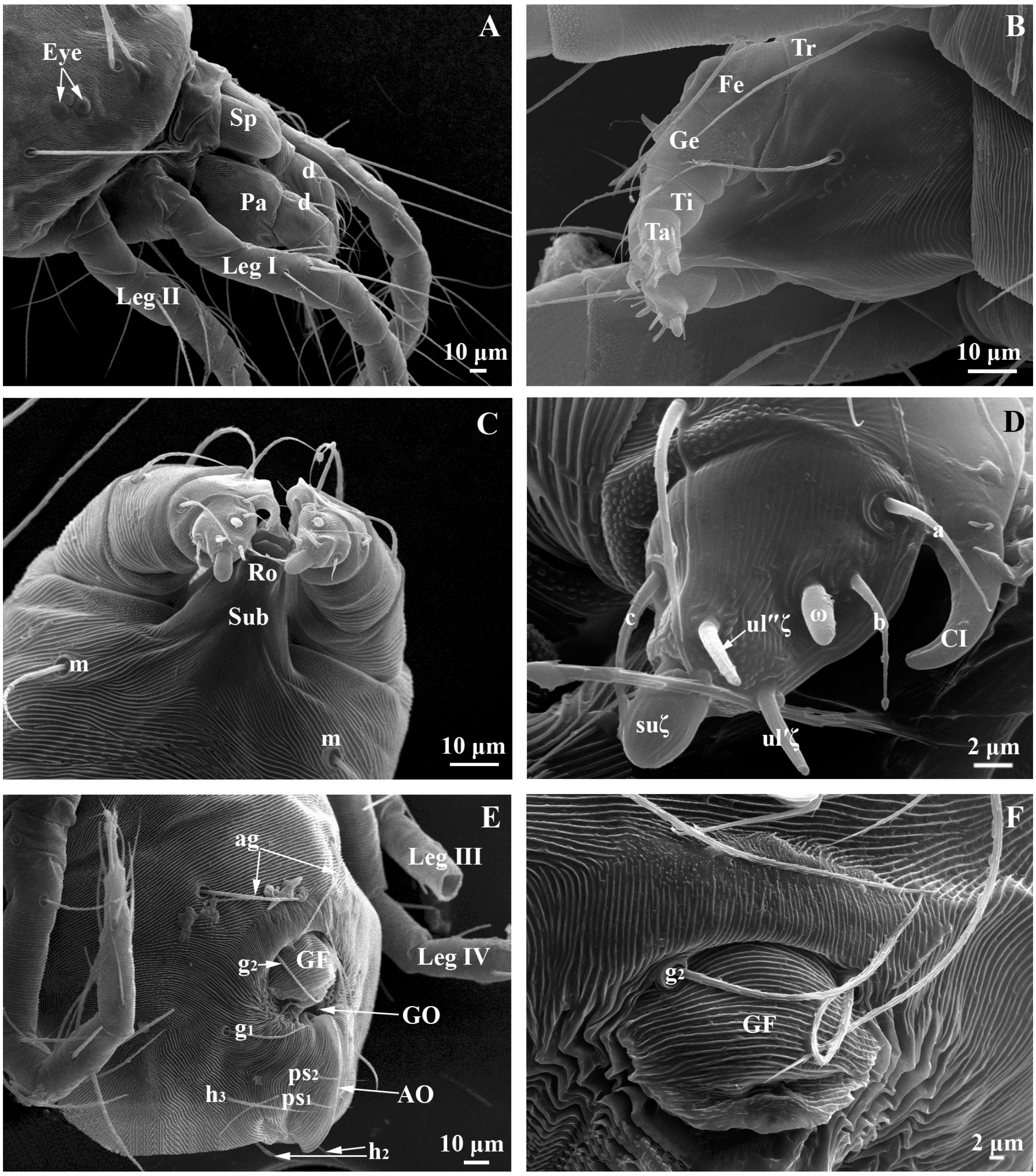

FIGURE 3. *Tetranychus turkestani* (adult female, SEM). A, Gnathosoma in lateral view, showing eye (*Eye*), palpfemoral seta (*d*), palpus (*Pa*), and stylophore (*Sp*); B, Pedipalp in lateral view, showing trochanter (*Tr*), femur (*Fe*), genu (*Ge*), tibia (*Ti*) and tarsus (*Ta*); C, Gnathosoma in ventral view, showing rostrum (*Ro*), subcapitular setae (*m*) and subcapitulum (*Sub*); D, Palptarsus in ventral view, showing palpotibial claw (*CI*), palpotarsal eupathidial spinneret (*suζ*), eupathidium (*ul′ζ* and *ul″ζ*), setae (*a*, *b* and *c*), solenidion (*ω*); E, Opisthosoma in ventral view, showing aggenital setae (*ag*), anal opening (*AO*), genital flap (*GF*), genital opening (*GO*), genital setae (g_1 and g_2), para-anals (h_3), post-anals (h_2) and pseudanal setae (ps_1 and ps_2); F, Genital region.

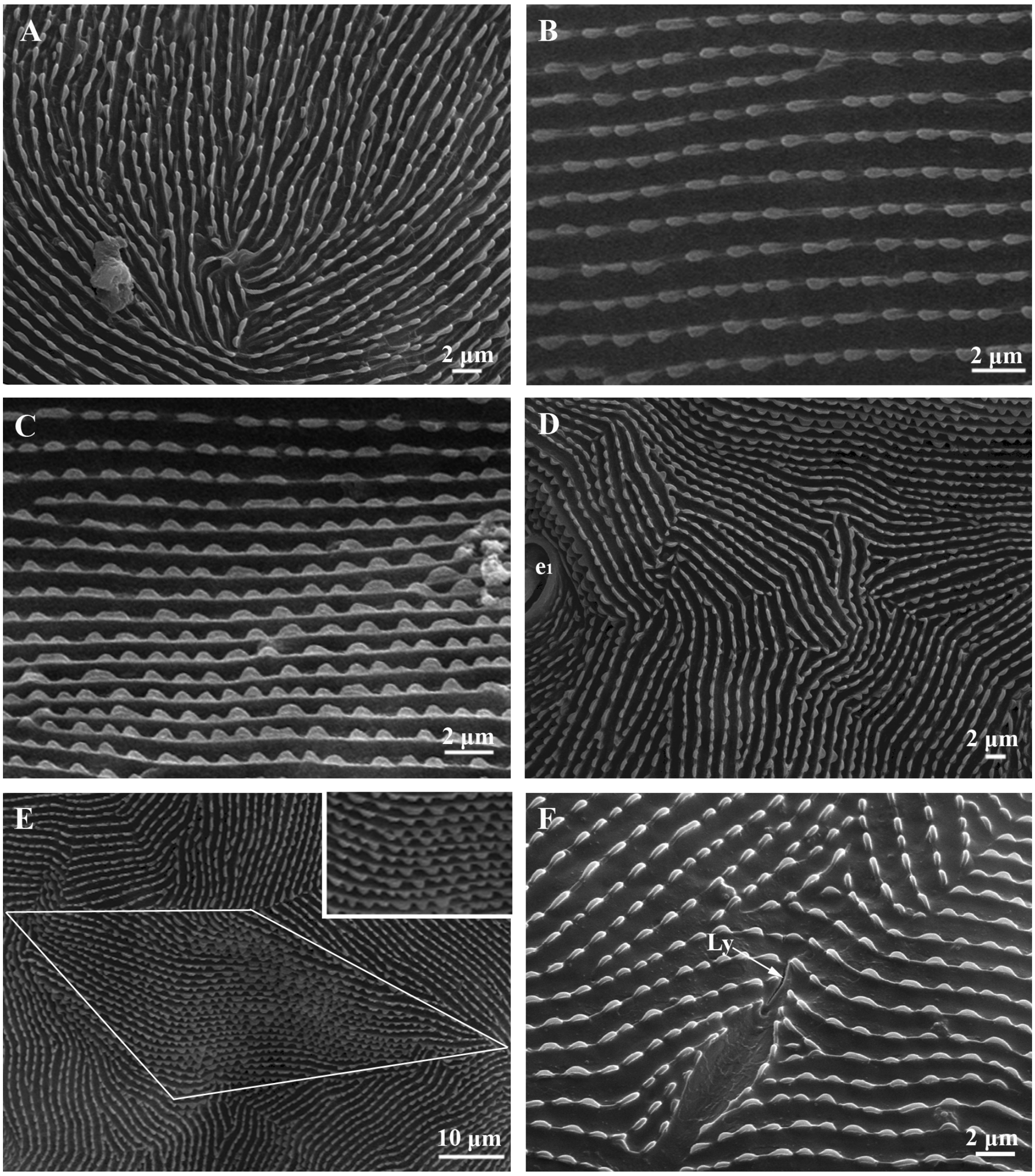

FIGURE 4. *Tetranychus turkestani* (adult female, SEM). A, The striae and integumentary lobes between the setae v_2 and sc_1; B, C The striae and integumentary lobes between the setae c_1, d_1 and e_1; D, The striae and integumentary lobes between the setae e_1; E, The striae and integumentary lobes between the setae e_1 and f_1; F, lyrifissure (*Ly*).

Gnathosoma

Chelicera: The shape of the stylophore (*Sp*) and stylet (*St*) is similar to that of adult female (Figs. 6C, 7A). *Palpus* (*Pa*) (Fig. 7A) also has 5 segments (Fig. 7B). The palpfemoral seta (*d*) is a short, stout, spine-like process (Fig. 7B). The palptarsus also has seven smooth-surfaced projections (*suζ*, *ω*, *ul'ζ*, *ul''ζ*, *a*, *b* and *c*) (Fig. 7C). Eupathidial spinneret (*suζ*) is obviously shortened and smaller than that in female. *Subcapitulum* (*Sub*), *rostrum* (*Ro*) and *peritreme* (*Pe*) are similar to those of adult female (Figs. 6C, 7C). The rostral gutter (*RG*) is located on the dorsal surface of the rostrum (Fig. 7B).

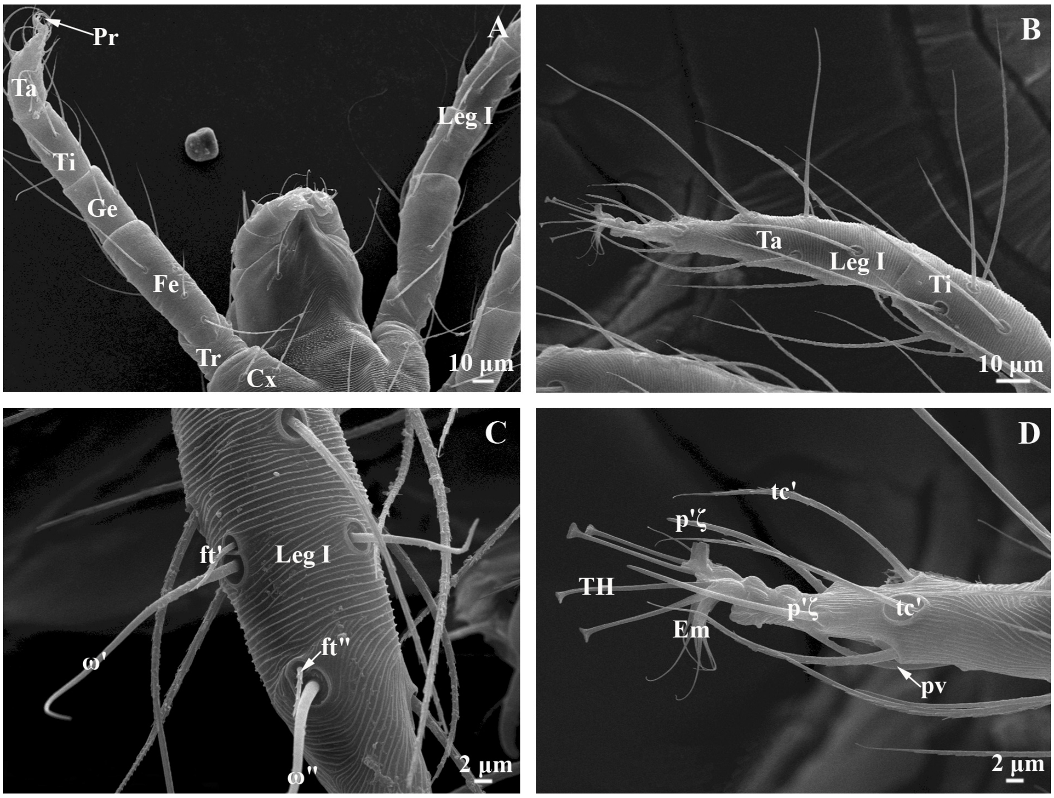

FIGURE 5. *Tetranychus turkestani* (adult female, SEM). A, Leg I in ventral view, showing coxa (*Cx*), trochanter (*Tr*), femur (*Fe*), genu (*Ge*), tibia (*Ti*), tarsus (*Ta*) and pretarsus (*Pr*); B, Tibia (*Ti*) and Tarsus (*Ta*) I in lateral view; C, Duplex setae (*ω', ft'*and *ω", ft"*); D, Tarsus and pretarsus I in lateral view, showing empodium (*Em*), prorals (*p'ζ*), tenent hairs (*TH*), tectal setae (*tc'*) and primiventrals (*pv*).

Idiosoma

Dorsum has fourteen pairs of dorsal setae (v_2, sc_1, sc_2, c_1, c_2, c_3, d_1, d_2, e_1, e_2, f_1, f_2, h_2 and h_3) (Figs. 6A, 7D).

Venter: The chaetotaxy includes six pairs of coxisternal setae (*1b*, *1c*, *2b*, *2c*, *3b* and *4b*), three pairs of intercoxal setae (*1a*, *3a* and *4*a), one pair of aggenital setae (*ag*) (Fig. 6B), two pairs of genital setae (g_1 and g_2) and two pairs of pseudanal setae (ps_1 and ps_2) (Fig. 7D).

Aedeagus: The shaft (*Sh*) of aedeagus is bent back to form a large terminal knob (*TK*) with an anterior projection that is blunt and a posterior projection that is acute. There is an obvious angle on the posterior projection near the 1/3 region (Fig. 6D).

Legs also have 7 segments. There are nine tactile setae and four solenidion on tibia I (Fig. 8B). The shape and situation of the duplex setae (*ω'*, *ft'* and *ω"*, *ft"*) are similar to those of adult female (Figs. 8A, 8C). The primilaterals (*pl'*, *pl"*) are located laterally and apically on tarsus I (Fig. 8D). The primiventrals (*pv*) is located ventrally (Fig. 8D). Empodium I (*Em*) consists of a claw-like structure with a strong mediodorsal spur about one half of the appendage (Fig. 8D). The claws of tarsus I are reduced to two pairs of tenent hairs (*TH*) (Fig. 8D).

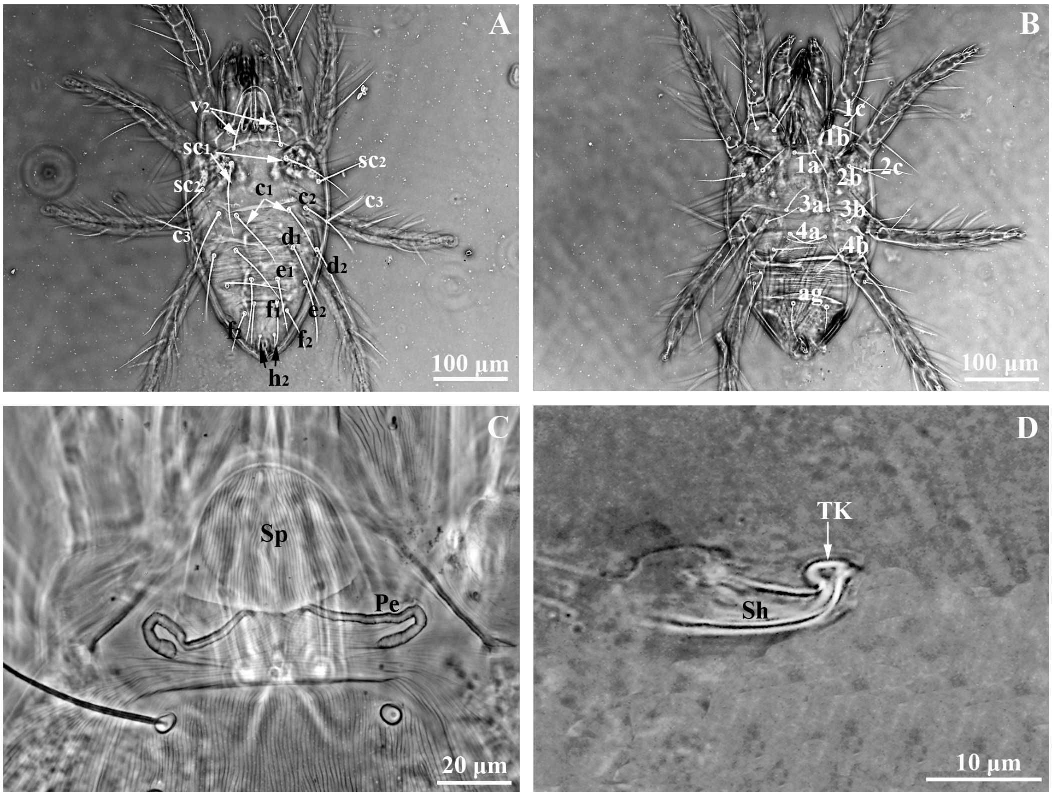

FIGURE 6. *Tetranychus turkestani* (adult male, LM). A, Dorsal view; B, Ventral view; C, Peritreme (*Pe*) and stylophore (*Sp*) in dorsal view; D, Aedeagus in lateral view, showing shaft (*Sh*) and terminal knob (*TK*).

Eggs (*n*=10)

It is smooth and spherical in shape with a diameter of about 129.55 ± 1.86 µm (Figs. 1A, 9D). The freshly laid eggs are colorless and transparent (Fig. 9A) and then gradually become canary yellow to dark yellow within one or two days (Figs. 9B, 9C). Eye spots appear redon the third day (Fig. 9C).

Larva (*n*=10)

Body 223.85 ± 6.24 µm long and 139.96 ± 5.30 µm wide (Figs. 10A, 10B), from transparent to turn sap green after feeding (Fig. 1B), bearing three pairs of legs.

Palptarsus has seven smoothly surfaced projections (*suζ*, *ω*, *ul′ζ*, *ul″ζ*, *a*, *b* and *c*) (Fig. 10C). Eupathidial spinneret (*suζ*) is a slender cylinder structure, and its length is about three times its width. The shapes of the solenidion (*ω*), two eupathidia (*ul′ζ* and *ul″ζ*) and three setae (*a*, *b* and *c*) are similar to those of adult female (Fig. 10C).

Dorsum: Larvae have fourteen pairs of dorsal setae (v_2, sc_1, sc_2, c_1, c_2, c_3, d_1, d_2, e_1, e_2, f_1, f_2, h_2 and h_3) (Figs. 10A, 10D).

Venter: The chaetotaxy includes one pair of coxisternal setae (*1b*) (Fig. 10B), two pairs of intercoxal setae (*1a* and *3a*) (Fig. 10B) and two pairs of pseudanal setae (ps_1 and ps_2) (Fig. 10D).

Legs: Leg chaetotaxy as follows: I-1-0-3-4-6-7 + 1 duplex; II- 0-0-3-4-5-7 + 1 duplex; III-0-0-2-2-5-6 (Figs. 11A–11C).

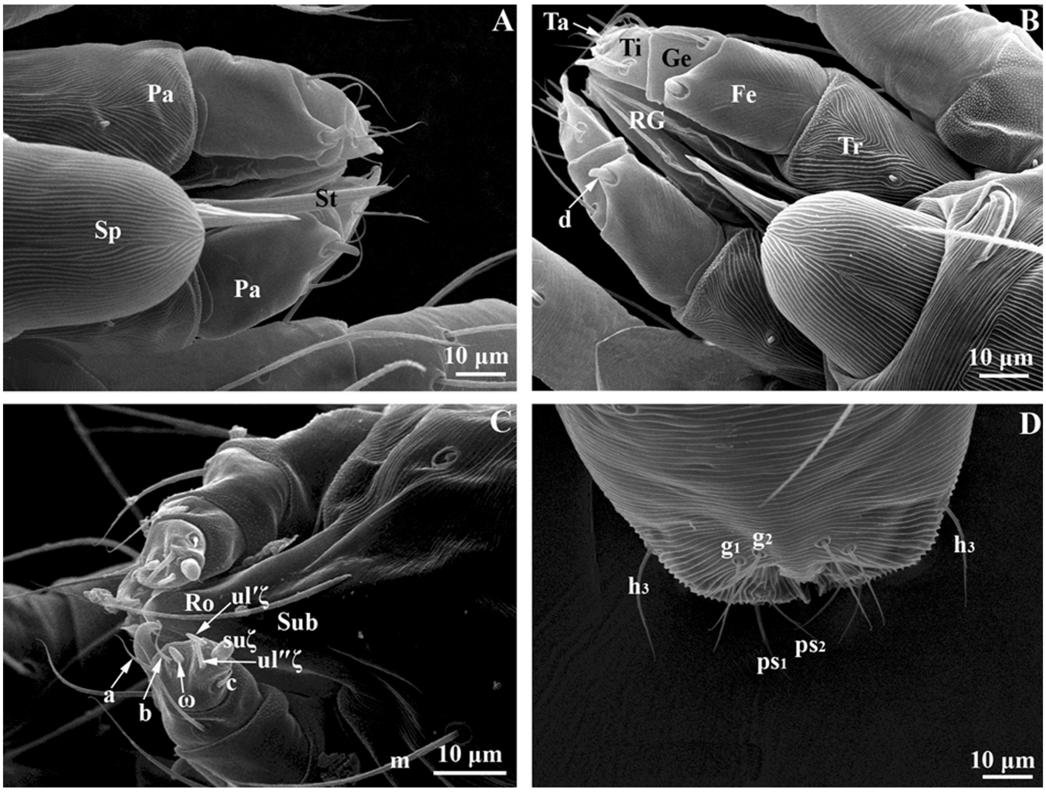

FIGURE 7. *Tetranychus turkestani* (adult male, SEM). A, B, Gnathosoma in dorsal view, showing palpi (*Pa*), rostral gutter (*RG*), stylophore (*Sp*), stylet (*St*), palpfemoral seta (*d*), trochanter (*Tr*), femur (*Fe*), genu (*Ge*), tibia (*Ti*) and tarsus (*Ta*); C, Gnathosoma in ventral view, showing palpotarsal eupathidial spinneret (*suζ*), eupathidium (*ul′ζ* and *ul″ζ*), rostrum (*Ro*), setae (*a*, *b* and *c*), solenidion (*ω*), subcapitular setae (*m*) and subcapitulum (*Sub*); D, Opisthosoma in ventral view, showing genital setae (g_1 and g_2), para-anals (h_3) and pseudanal setae (ps_1 and ps_2).

Protonymph (*n*=10)

Body 267.87 ± 5.23 µm long and 176.69 ± 5.42 µm wide (Figs. 12A, 12B), yellow-green after incubation, and it will turn dark green after it's sucking the sap of plants (Fig. 1C).

Palptarsus has seven smooth projections (*suζ*, *ω*, *ul′ζ*, *ul″ζ*, *a*, *b* and *c*) which are similar to those of larvae (Fig. 12C).

Dorsum: Protonymph has fourteen pairs of dorsal setae (v_2, sc_1, sc_2, c_1, c_2, c_3, d_1, d_2, e_1, e_2, f_1, f_2, h_2 and h_3) (Figs. 12A, 12D).

Venter: In addition to those setae in larva, three pairs of coxisternal setae (*1c*, *2b* and *3b*) (Fig. 12B) and one pair of aggenital setae (*ag*) are added (Fig. 12D).

Legs: Leg chaetotaxy as follows: I-2-0-3-4-6-9 + 2 duplexes; II- 1-0-3-4-5-9 + 1 duplex; III-1-0-2-2-5-8; IV-0-0-2-2-5-6 (Figs. 13A–13D).

Deutonymph (*n*=10)

Body 372.89 ± 11.78 µm long and 212.93 ± 7.10 µm wide (Figs. 14A, 14B); light-green to dark-green in color (Fig. 1D).

Palptarsus has seven smooth projections (*suζ*, *ω*, *ul′ζ*, *ul″ζ*, *a*, *b* and *c*) which are similar to those in adult female (Fig. 14C).

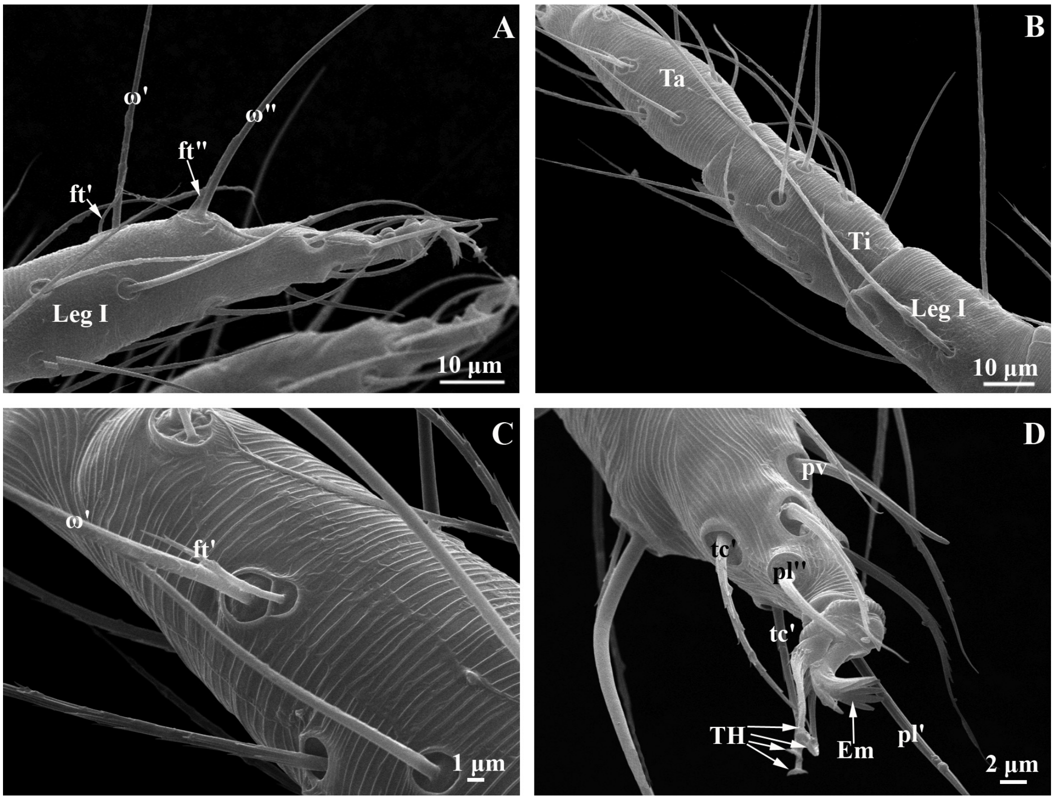

FIGURE 8. *Tetranychus turkestani* (adult male, SEM). A, Tarsus and pretarsus I in lateral view; B, Tibia (*Ti*) and Tarsus (*Ta)* I in lateral view; C, Duplex setae (*ω'* and *ft'*); D, Tarsus and pretarsus I in lateral view, showing empodium (*Em*), primilaterals (*pl'* and *pl''*), primiventrals (*pv*), tenent hairs (*TH*) and tectal setae (*tc'*).

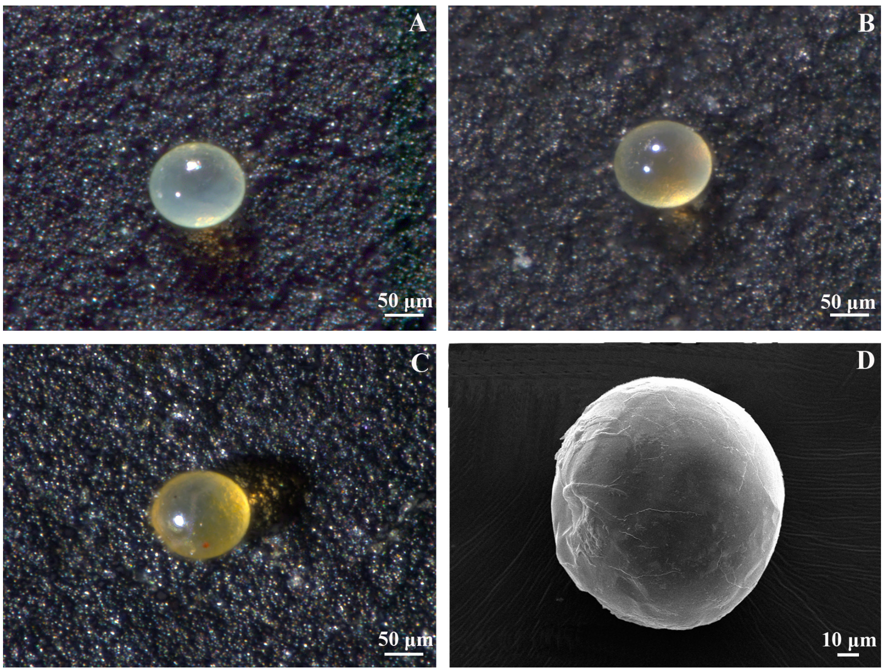

FIGURE 9. *Tetranychus turkestani* (egg, LM, SEM). A, 24 hr; B, 48 hr; C, 72 hr; D, 48 hr.

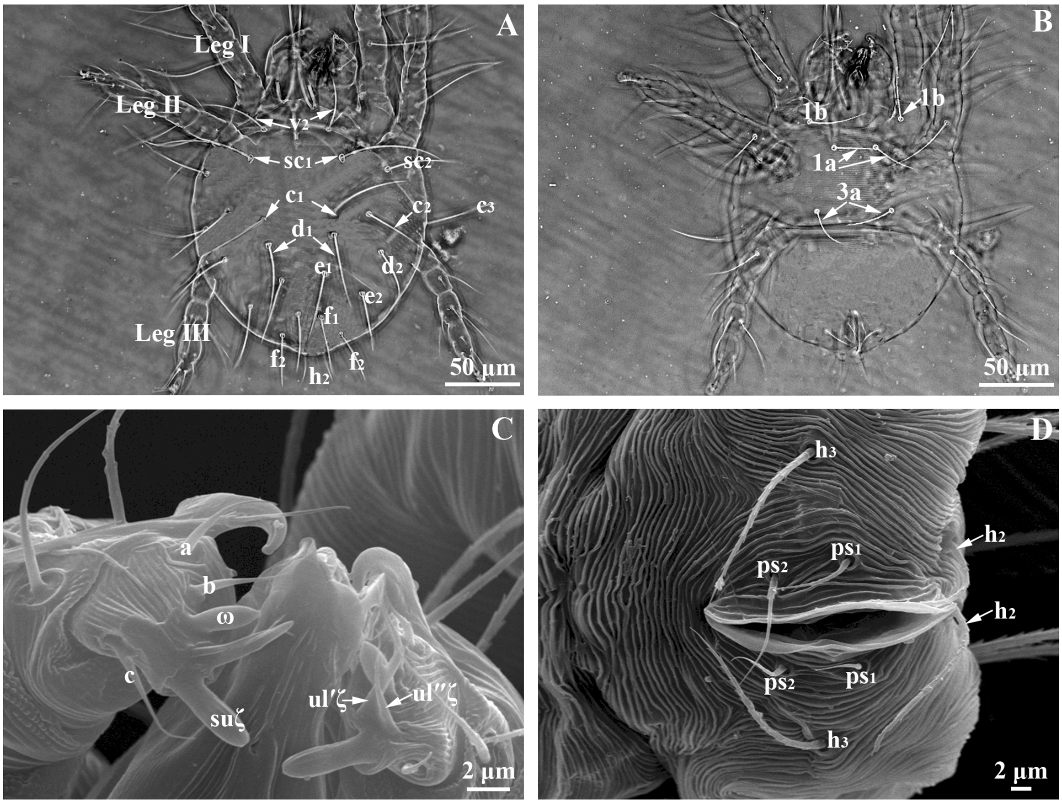

FIGURE 10. *Tetranychus turkestani* (larva, LM, SEM). A, Dorsal view; B, Ventral view; C, Palptarsus in ventral view, showing eupathidial spinneret (*suζ*), eupathidium (*ul′ζ* and *ul″ζ*), setae (*a*, *b* and *c*), and solenidion (*ω*); D, Opisthosoma in ventral view, showing para-anals (h_3), post-anals (h_2) and pseudanal setae (ps_1 and ps_2).

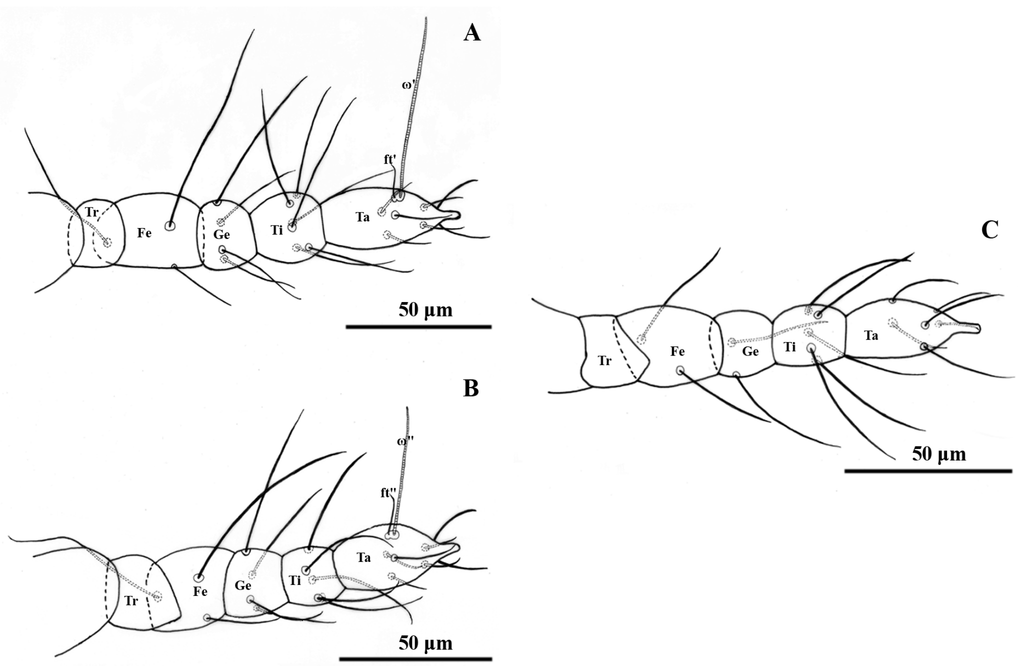

FIGURE 11. *Tetranychus turkestani* (larva). A, Leg I; B, Leg II; C, Leg III.

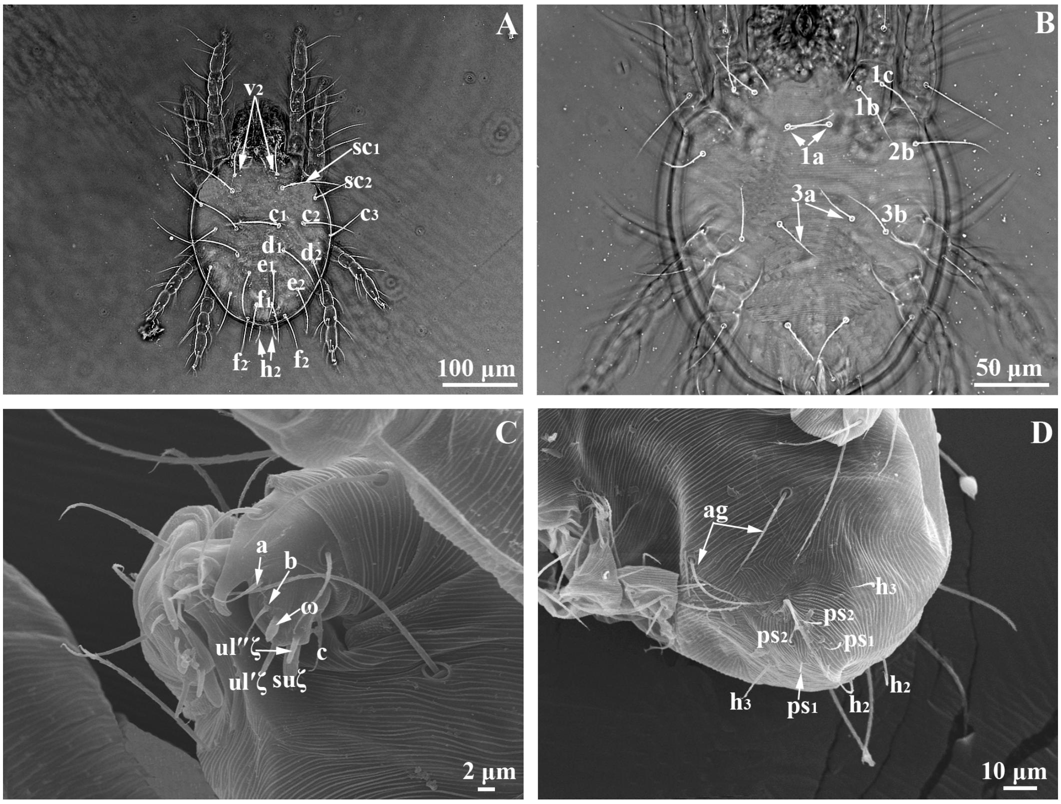

FIGURE 12. *Tetranychus turkestani* (protonymph, LM, SEM). A, Dorsal view; B, Ventral view; C, Palptarsus in ventral view, showing eupathidial spinneret (*suζ*), eupathidium (*ul′ζ* and *ul″ζ*), setae (*a*, *b* and *c*) and solenidion (*ω*); D, Opisthosoma in ventral view, showing aggenital setae (*ag*), para-anals (h_3), post-anals (h_2) and pseudanal setae (ps_1 and ps_2).

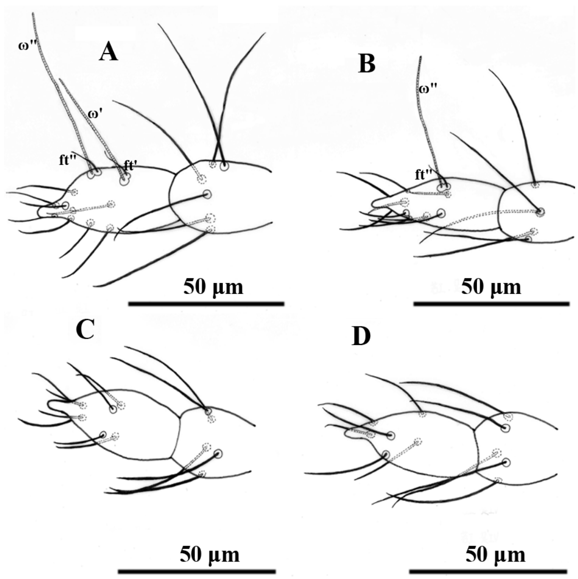

FIGURE 13. *Tetranychus turkestani* (protonymph). A, Tibia and tarsus I; B, Tibia and tarsus II; C, Tibia and tarsus III; D, Tibia and tarsus IV.

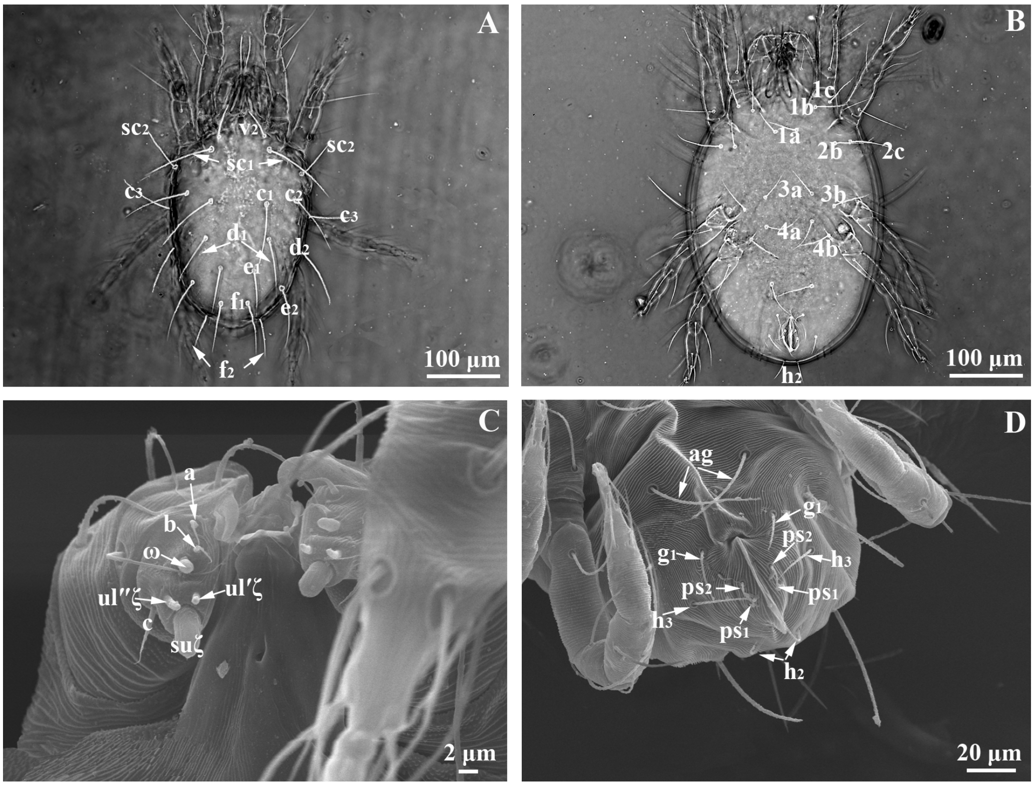

FIGURE 14. *Tetranychus turkestani* (deutonymph, LM, SEM). A, Dorsal view; B, Ventral view; C, Palptarsus in ventral view, showing eupathidial spinneret (*suζ*), eupathidium (*ul′ζ* and *ul″ζ*), setae (*a*, *b* and *c*) and solenidion (*ω*); D, Opisthosoma in ventral view, showing aggenital setae (*ag*), genital setae (g_1), para-anals (h_3), post-anals (h_2) and pseudanal setae (ps_1 and ps_2).

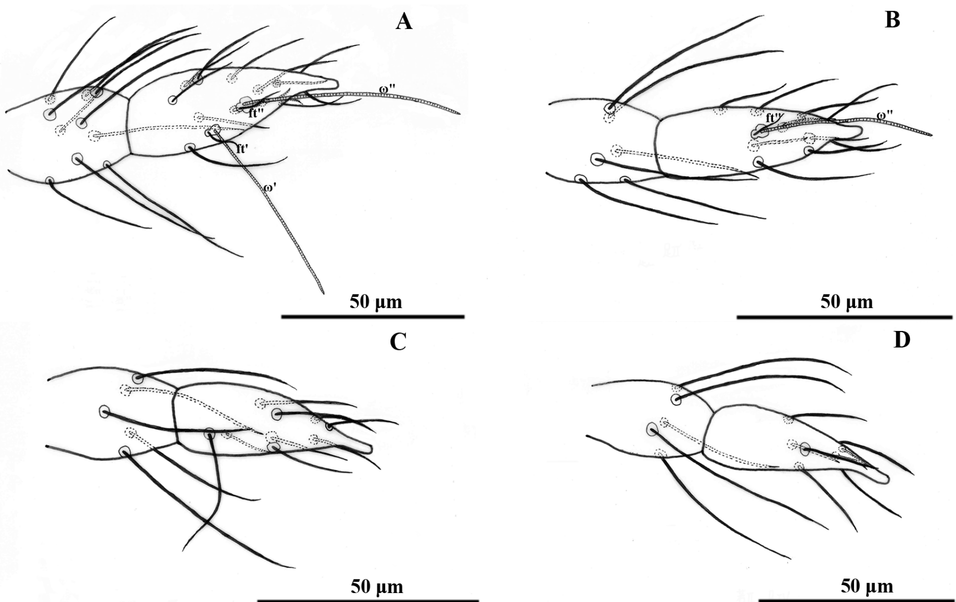

FIGURE 15. *Tetranychus turkestani* (deutonymph). A, Tibia and tarsus I; B, Tibia and tarsus II; C, Tibia and tarsus III; D, Tibia and tarsus IV.

Dorsum bears fourteen pairs of dorsal setae (v_2, sc_1, sc_2, c_1, c_2, c_3, d_1, d_2, e_1, e_2, f_1, f_2, h_2 and h_3) (Figs. 14A, 14D).

Venter: In addition to those setae in protonymph, two pairs of coxisternal setae (*2c* and *4b*) (Fig. 14B), one pair of intercoxal setae (*4a*) (Fig. 14B) and one pair of genital setae (g_1) (Fig. 14D) are added. Genital folds begin to form.

Legs: Leg chaetotaxy as follows: I-2-1-5-5-10-13 + 2 duplexes; II- 2-1-4-4-6-10 + 1 duplex; III-1-1-2-3-5-9; IV-1-0-2-3-5-8 (Figs. 15A-15D).

Comparison of the lengths of dorsal setae of different development stages

In female the lengths of the dorsal setae increase significantly as the mites grow from larva to adult (Table 1). Seta sc_1 is the longest at the adult stage and shortest at the larval stage. All dorsal setae of adult female are significantly longer than those of male. Lengths of v_2, sc_2, c_2, d_1, d_2 and e_2 don't change significantly in deutonymph and adult male. The length of h_3 shows no significant differences at the stages of larva, protonymph and adult male.

TABLE 1. The length of dorsal setae of *T. turkestani* at different development stages (*n*=10).

Length (μm)	Development stage				
	Larva	Protonymph	Deutonymph	Female adult	Male adult
v_2	46.69 ± 0.59 a	50.19 ± 0.67 b	59.63 ± 0.46 c	75.74 ± 1.84 d	61.03 ± 0.48 c
sc_1	65.76 ± 0.98 a	89.12 ± 0.57 b	107.13 ± 0.94 d	139.91 ± 1.30 e	103.10 ± 0.60 c
sc_2	48.51 ± 0.59 a	59.82 ± 0.44 b	77.51 ± 0.57 c	109.22 ± 1.39 d	75.81 ± 0.53 c
c_1	53.66 ± 0.81 a	72.02 ± 0.54 b	98.39 ± 0.97 d	132.76 ± 1.70 e	90.70 ± 0.88 c
c_2	52.90 ± 0.97 a	70.23 ± 0.97 b	92.86 ± 0.77 c	129.71 ± 0.89 d	91.61 ± 0.62 c
c_3	47.01 ± 0.58 a	59.69 ± 1.09 b	81.69 ± 0.84 d	108.97 ± 1.71 e	78.29 ± 1.25 c
d_1	48.61 ± 1.30 a	69.83 ± 0.88 b	92.50 ± 0.89 c	129.06 ± 1.80 d	90.38 ± 0.80 c
d_2	47.48 ± 0.52 a	68.49 ± 0.82 b	89.70 ± 0.41 c	131.68 ± 1.39 d	90.42 ± 1.17 c
e_1	46.07 ± 0.73 a	66.62 ± 0.60 b	85.84 ± 0.58 d	121.80 ± 1.51 e	83.28 ± 0.44 c
e_2	44.08 ± 0.40 a	64.10 ± 1.39 b	87.20 ± 0.94 c	124.30 ± 1.20 d	85.51 ± 0.46 c
f_1	37.44 ± 0.90 a	56.56 ± 0.64 b	74.88 ± 0.65 d	106.83 ± 0.77 e	59.67 ± 0.94 c
f_2	31.36 ± 0.27 a	46.72 ± 0.82 b	64.77 ± 0.57 d	94.70 ± 1.15 e	55.18 ± 0.73 c
h_2	19.63 ± 0.76 a	22.97 ± 0.67 b	27.35 ± 0.87 c	44.73 ± 1.06 d	20.40 ± 0.45a
h_3	22.95 ± 0.26 a	24.00 ± 0.30 a	28.37 ± 0.49 b	43.15 ± 0.56 c	23.33 ± 0.18 a

Note: Data in the table are MEAN±SE. Different letter labels in the same line indicate a significant difference (*P*<0.05).

Discussion

The shapes of the stylophore, stylets, palpi and rostral gutter of *T. turkestani* are similar to other spider mites, such as *T. atlanticus*, *T. urticae*, *Oligonychus punicae* and *Panonychus citri* (Baker & Connell 1963; Bostanian & Morrison 1973; Hislop & Jeppson 1976; Razaq *et al*. 2000). The stylophore and rostral gutter have the function of protecting the stylets, and the rostral gutter serves as a vessel for stylets to protract and retract (Razaq *et al*. 2000). In comparison to Eriophyoidea which has short stylets and are capable of very shallow penetration into a plant (Jeppson *et al*. 1975), Tetranychoidea possesses long stylets which could easily penetrate plant tissues, so it may kill the plant cells (Evans *et al*. 1961).

The pattern of the striae between setae e_1 and f_1 may be of diagnostic value in adult females in Tetranychidae (Lindquist 1985). The ultrastructure of the striae and integumentary lobes are also of diagnostic importance in distinguishing diapausing and non-diapausing populations of the same species or between closely related species (Boudreaux & Dosse 1963; Dosse & Boudreaux 1963; Jeppson *et al*. 1975). The morphological characters of the striae and integumentary lobes of *T. urticae* have been reported (Brandenburg & Kennedy 1981; Mollet & Sevacherian 1984). There is also a diamond-shaped area between the setae e_1 and f_1 in *T. urticae*, and the shape of integumentary lobe is different in different regions (Carbonnelle & Hance 2004). The shape of integumentary lobes of *T. turkestani* is similar to that of feeding green females of *T. urticae* collected in Lattes, France (Carbonnelle & Hance 2004).

Spider mites have the habit of spinning webs (Saito 1977, 1983). Adult female of *T. turkestani* covers its eggs and lavae with webs to protect them from predators and other external factors. The eupathidial spinneret is more developed in adult female than in male. The shape of the eupathidial spinneret of *T. turkestani* adults is similar to that of *T. urticae* and *T. truncatus* (Bostanian & Morrison 1973; Sakunwarin *et al*. 2004), but different from that of *T. bunda* and *T. musae* (Flechtmann & Knihinicki 2002; Auger *et al.* 2008). It is much slender, about three times as long as wide in *T. bunda* (Flechtmann & Knihinicki 2002) and as long as wide in *T. musae* (Auger *et al.* 2008).

Many sensory receptors are found on the tip of the mouthparts and legs of mites (Alberti & Coons 1999; Walter & Proctor 1999). Some scholars have studied the sensilla of *T. urticae* and *T. truncatus*, and they concluded that the solenidion and two eupathidia on palptarsus are chemoreceptors, the three setae are mechanosensitive sensilla, and the solenidia (ω' and ω'') of duplex setae are chemosensitive sensilla (Bostanian & Morrison 1973; Sakunwarin *et al*. 2004). The six sensilla on the palptarsus of *T. turkestani* adults are similar in shape and position to those of *T. urticae* and *T. truncatus.*

Most of the articles mainly describe the leg chaetotaxy of female and male mites (Stone 1986; Ehara & Gotoh 1992; Ehara 1995; Flechtmann & Knihinicki 2002), and we studied the leg chaetotaxy of all stages. There is a great change in the leg chaetotaxy of tibia and tarsus from larva to deutonymph, and the chaetotaxy of leg III of larva is consistent with the chaetotaxy of leg IV of protonymph. The shapes of the tarsal claw and empodium in Tetranychidae are important taxonomic characters (Wang 1981). The shape of the empodium I of *T. turkestani* is different from that of *T. musae* (Auger *et al.* 2008). The empodium I of female adult *T. turkestani* have three pairs of minute, attenuate hair-like processes, while that of *T. musae* bear three pairs of proximoventral hairs and a large mediodorsal spurs (Auger *et al.* 2008). The empodium I of male adult *T. turkestani* has a similar shape as the empodium II of that of *T. lintearius*, which consists of three pairs of distally fused proximoventral spurs and possesses a strong mediodorsal spur (Stone 1986). However, the empodium I of male *T. musae* adults consists of a double claw-like structure with a strong mediodorsal spur (Auger *et al.* 2008). To summarize, this paper increases understanding of the external morphological characteristics of *T. turkestani*.

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