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A new species of *Dactylopius* Costa (*Dactylopius gracilipilus* sp. nov.) (Hemiptera: Coccoidea: Dactylopiidae) from the Chihuahuan Desert, Texas, U.S.A.

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Abstract

A new species of *Dactylopius* Costa (*Dactylopius gracilipilus* Van Dam & May) is described and illustrated. It is morphologically similar to *Dactylopius tomentosus* (Lamarck), but has more gracile truncate setae, abundant simple pores dorsally, and appears to be host-restricted to *Corynopuntia* Knuth (Cactaceae: Opuntioidea).

Key words: cochineal, Dactylopiidae, taxonomy, Chihuahuan Desert, host-restricted

Introduction

The scale insects (Hemiptera: Coccoidea) are a diverse group of mainly sap-sucking insects with at least 30 families and around 8000 species. Female scale insects have a simplified morphology and lack all trace of wings whereas the males are minute, have a single pair of wings (mesothoracic) and completely lack mouthparts. Within the Coccoidea, the Dactylopiidae Costa is a small monogeneric family of nine species (De Lotto 1974). *Dactylopius* spp. are of significant economic and biological importance for three reasons: 1, carminic acid is extracted from dried pulverized bodies of *D. coccus* Costa and then used as a red dye globally, primarily as food coloring (Perez Guerra & Kosztarab 1992; FAO 2003; Rodriguez & Pascual 2004; Portillo & Zimmermann 2008; Chávez-Moreno *et al.* 2009); 2, five of the nine *Dactylopius* species have been used successfully as biological control agents of invasive cacti (Hosking *et al.* 1994; Githure *et al.* 1999; Singh 2004; Zimmermann *et al.* 2004; Mathenge *et al.* 2009); and 3, *Dactylopius* spp. can be invasive, threatening native cacti and cochineal production in areas where they are non-native (Portillo & Zimmermann 2008; Lopes *et al.* 2009; Chávez-Moreno *et al.* 2011; Santos *et al.* 2011).

Dactylopius has a disjunct, amphitropic distribution, with four endemic species in North America (including Mexico) and five endemic species in South America from Peru southwards, particularly in northern Argentina (De Lotto 1974; Perez Guerra & Kosztarab 1992; Ben-Dov & Marotta 2001; Claps & de Haro 2001). Dactylopiidae only infest members of Cactaceae, including both Cactoidea and Opuntioidea (De Lotto 1974; Perez Guerra & Kosztarab 1992; Claps & de Haro 2001). A new species has been found on the *Corynopuntia schottii* (Engelmann) Knuth species complex (Benson 1982; Ralston & Hilsenbeck 1992; Griffith 2002), in Chihuahuan Desert of Big Bend National Park, Texas, and is described below.

Material and Methods

All specimens were collected by the first author under Big Bend National Park permit BIBE-2008-SCI-0034. Slide mounting procedures follow protocols of the United States Department of Agriculture Systematic Entomology Laboratory (USDA 2011).
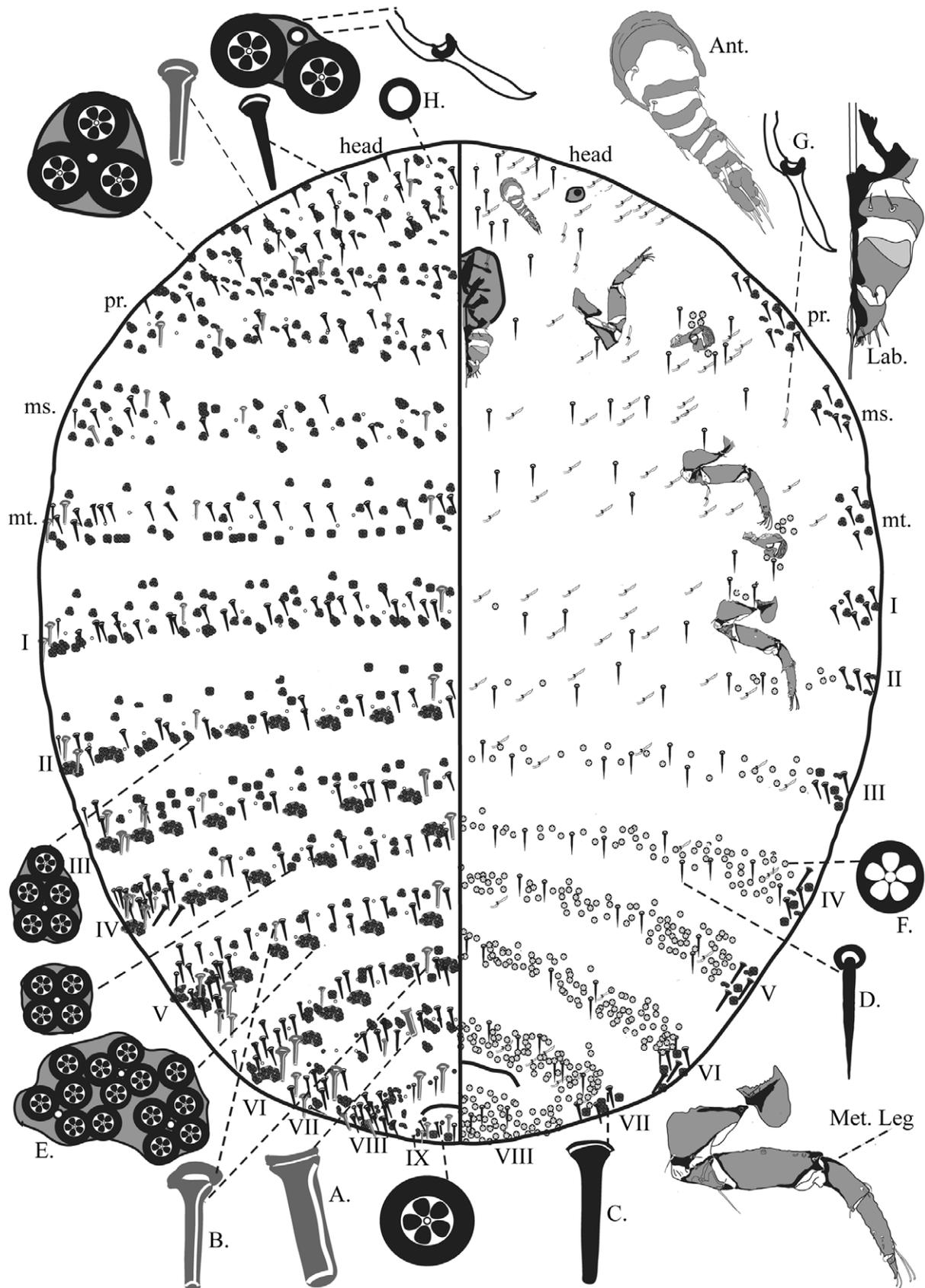
FIGURE 1. *Dactylopius gracilipilus* **sp. nov.** adult female, where Ant = antennae, Lab = labium, Met. Leg = metathoracic leg, pt = prothorax, ms = mesothorax, mt = metathorax, I–IX = abdominal segments, A = large stout truncate setae with parallel sides (shown in gray), B = smaller truncate setae with parallel sides (shown in gray), C = truncate setae with sides tapering towards apex, D = hair-like setae, E = wide-rimmed quinquelocular pore cluster, F = narrow-rimmed quinquelocular pore, G = macrotubular duct, and H = simple pore.

Line drawings follow standard conventions for describing Coccoidea, with venter on the right and dorsum on the left (Kondo *et al.* 2006). All specimens listed in this publication were studied to make the line drawings. Detailed illustrations of heavily sclerotized structures such as legs etc. were made by using a Nikon Eclipse E600 (Nikon, Japan) compound scope, a Spot 11.3 digital camera and Spot 4.5 software (Sterling Heights, MI, U.S.A.) to create digital photographs, then montaged together using ImageJ 1.44 software (Rasband 1997) with Extended Depth of Field (Forster *et al.* 2004) add on. Line drawings were then done using Adobe Illustrator CS5® software using an Intuos®2 graphics tablet (WACOM, Japan).

Descriptive terminology follows that of De Lotto (1974) and Perez Guerra and Kosztarab (1992).

Dactylopius Costa, 1835

Dactylopius Costa, 1835:16
Selected reviews: De Lotto 1974; Perez Guerra & Kosztarab 1992; Claps & de Haro 2001.
Type species: *Dactylopius coccus* Costa, 1835.

Generic diagnosis. Synapomorphic characters that define adult female Dactylopiidae include: presence of numerous truncate setae over dorsal surface of abdomen; quinquelocular pore clusters on a sclerotized plate each frequently associated with one or more tubular ducts.

Distribution. *Dactylopius* has been introduced both accidentally and intentionally into many parts of the world where suitable habitat occurs (Portillo & Zimmermann 2008). *Dactylopius* is native to arid regions of the western hemisphere where native cacti, especially opuntioid cacti, occur.

Diagnosis. *Dactylopius gracilipilus* **sp. nov.** keys out to *D. tomentosus* (Lamarck) in couplet 5 in Perez Guerra and Kosztarab (1992). Below is an additional couplet to include *D. gracilipilus*.

|		
5	Truncate cylindrical setae forming medial and submedial longitudinal rows on thorax and abdomen	5b
-	Truncate setae not forming various rows	6
5b	Large stout setae with parallel sides each less than 1.5 times as long as wide, present in medial and submedial longitudinal rows; simple pores entirely absent or rare on dorsum of abdomen; 10 or more wide-rimmed quinquelocular pores per cluster uncommon, and not forming distinctive transverse bands; host-plant *Cylindropuntia* spp	*D. tomentosus*
-	Large truncate setae with parallel sides each 1.5–2 times as long as wide, present in medial longitudinal rows, submedial rows less distinctive and made up of smaller setae; dorsum with abundant simple pores; clusters of wide-rimmed quinquelocular pores with more than 10 pores per cluster common, forming distinctive transverse bands; host-plant *Corynopuntia* spp . . . . *D. gracilipilus* **sp. nov.**

Dactylopius gracilipilus sp. nov.
(Figures 1–4)

Material Examined. All specimens are adult females, and deposited in UC Davis, R.M. Bohart Museum of Entomology, **Holotype,** (1adf) USA, Texas, Brewster Co., Big Bend National Park, N29º08.069' W103º02.335', host-plant *Corynopuntia schottii*, 30-viii-2009, coll. A.R. Van Dam.

Paratypes, (2adff) USA: Texas, Brewster Co., Big Bend National Park, N29º11.570' W103º01.382', host-plant *C. schottii*, 31-viii-2009, coll. A.R. Van Dam. (2adff) USA, Texas, Brewster Co., Big Bend National Park, N29º09.773' W103º00.554', host-plant *C. schottii*, 30-viii-2009, coll. A.R. Van Dam. (2adff) USA, Texas, Brewster Co., Big Bend National Park, N29º08.951' W103º00.431', host-pant *C. schottii*, 30-viii-2009, coll. A.R. Van Dam. (1adf) USA, Texas, Brewster Co., Big Bend National Park, N29º08.069' W103º02.335', host-plant *C. aggeria* (Ralston & Hilsenbeck) Griffith. 30-viii-2009, coll. A.R. Van Dam. (7adff) USA, Texas, Brewster Co., Big Bend National Park, N29º04.499' W103º06.293', host-plant *C. schottii*, 30-viii-2009, coll. A.R. Van Dam.

Description. Live material. Collected from cladodes of *Corynopuntia schottii* complex (Benson 1982; Ralston & Hilsenbeck 1992; Griffith 2002) (figs. 2–4). Superficially similar to other *Dactylopius* (save *D. coccus* and some populations of *D. ceylonicus* (Green), pers. obs.) with typical dense waxy secretions (figs. 2 & 3). Some infestations contained many male puparia.

Adult female.
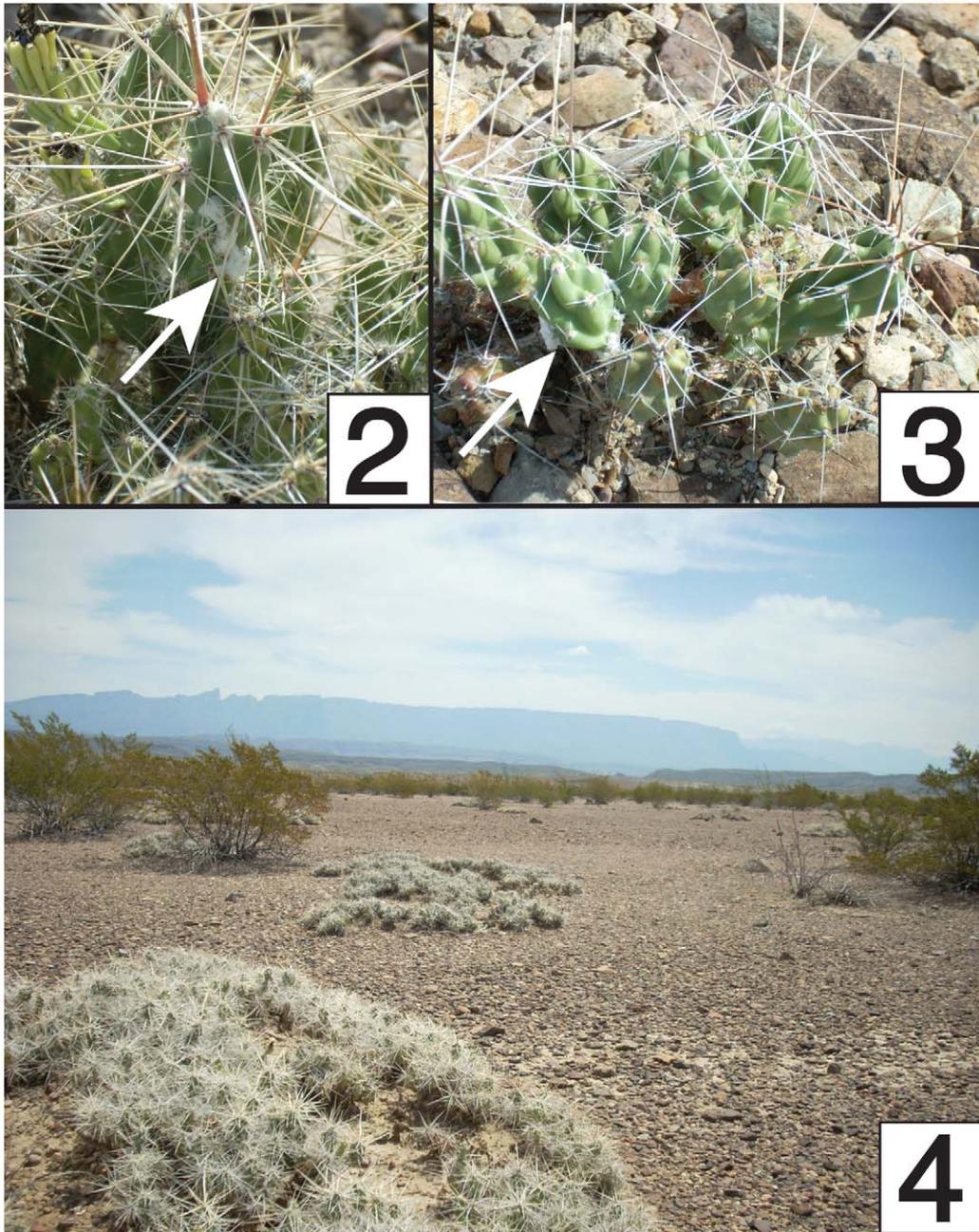
FIGURES 2–4. Plants of *Corynopuntia schottii* species complex infested with *Dactylopius gracilipilus* **sp. nov.** Arrows in Figs 2 and 3, indicate *D. gracilipilus* locations: Fig. 2 on *C. schottii*, Fig. 3 on *C. aggeria*, and Fig. 4 showing desert pavement habitat with *C. schottii* plants in foreground.

Mounted Material. Body oval, length each 1.95–2.84mm, widest point of metathorax each 1.12–2.38mm. Segmentation distinct on meso- and metathorax, and abdomen. Abdominal segmentation in Fig. 1 numbered as in Williams and Watson (1987).

Antennae six or seven segmented (six segmented in Holotype; segments III and IV fused or partially fused in 10 out of 15 specimens); total length 138–197μm. Segment I each 50–82μm wide, 29–62μm long with three hair-like setae; II 30–47μm wide, 7–17μm long, with two hair-like setae and one sensorial pit; III 32–43μm wide, 11–18μm long, [when fused, IV 22–35μm long]; IV 30–34μm wide, 11–16μm long, with two hair-like setae and two sensorial pits; V 21–31μm wide, 9–15μm long, with one fleshy seta; VI 20–28μm wide, 10–18μm long, with three hair-like setae and one fleshy seta; VII 19–23μm wide, 25–34μm long, with four hair-like setae and five fleshy setae.

Tentorial box 219–275µm wide, 214–283µm long, pentagonal, heavily sclerotized. Labium three segmented, 92–169µm wide, 107–155µm long, triangular in shape. Segment I with two pairs of hair-like setae; II with a single pair of hair-like seta on a paddle-shaped projection between segment II and III; apical segment with six pairs of setae, most apical two pairs stout and fleshy, others hair-like.

Spiracles all with a smooth opening, lacking jagged edges, appearing oval, with an inner projection; anterior atrium 47–60µm wide, with 2–7 narrow-rimmed quinquelocular pores and 1 or 2 hair-like setae; posterior spiracle with atrium 43–66µm wide, with 1 or 2 hair-like setae and 2–7 narrow-rimmed pores.

Legs not reduced, typical of other *Dactylopius* spp., each 310–450µm long, increasing in size posteriorly; each tarsus and claw with two digitules, knobbed at apex, tarsal digitules 37.5–57µm long, ungual digitules 24–41µm long; tarsal claw each with a minute denticle near apex; legs situated on small fleshy lobes, each with 0-2 hair-like setae and 1 or 2 narrow-rimmed quinquelocular pores.

Dorsum. Hair-like setae, each 3.75–7.5µm wide at basal collar, 10–30µm long, smallest on head increasing in size posteriorly towards abdominal segment X; setae scattered anteriorly on head, and prothorax; abdominal segments I–VII, with only 1 or 2 present along margins; abdominal segment VIII with 1 or 2 larger hair-like setae (each approximately 30µm long) near midline and with a single seta submedially; an additional pair present between the margin and submedial setae; abdominal segment IX with a hair-like seta on either side of midline only.

Truncate setae of two distinct types: (i) setae with parallel sides and (ii) setae with sides tapering towards apex. Type (i) truncate setae (shown in gray in Fig.1) with parallel sides, each 7.5–10µm wide at basal collar, 10–27.5µm long, smallest on head and increasing in size posteriorly; scattered on head and prothorax, but in two longitudinal lines medially and in indistinct submedial lines from mesothorax to abdominal segment VII (that medially on VII wider than all other type (i) setae, each 12.5–17.5µm wide at basal collar by 20–22.5µm long) plus 1-4 type (i) setae near margins on mesothorax and abdominal segments I-VII; abdominal segment VIII with 1 or 2 type (i) setae on either side of midline, but not submedially; abdominal segment IX with a single type (i) seta nearly adjacent to either side of midline with 2–3 more scattered near margin. Type (ii) setae with sides tapering towards apex, each 5–10µm wide at basal collar, 10–31µm long, smallest on head, increasing in size posteriorly; present in a scattered pattern across head and prothorax, but in distinct transverse bands on meso- and metathorax and all abdominal segments; abdominal segment VII with 1 or 2 near midline; present in clusters of 3-9 on margins of abdomen.

Simple pores each 3µm wide, abundant, scattered across dorsal surface, mainly in indistinct transverse bands on meso- and metathorax and all abdominal segments.

Wide-rimmed quinquelocular pores present mostly in clusters of 2–5 across head and prothorax, but with larger clusters of 5–21 in distinct transverse bands on meso- and metathorax and all abdominal segments except only present singly or in clusters of 2 or 3 in abdominal segment VIII; larger clusters tending to be near margins of abdomen.

Venter. Eyespots each 43–59µm wide, 30–47µm long. Hair-like setae, each 5–7.5µm wide at basal collar 12.5–22.5µm long, smallest on head increasing in size posteriorly; setae tending to be scattered across medial surface of head and thorax but forming indistinct transverse bands across venter of abdominal segments. Narrow-rimmed quinquelocular pores present in dense bands on abdominal segments IV–VIII but fewer on abdominal segments II and III and segment I with only 2 narrow rimmed pores close to midline and with a group near margin on II; also present just posterior and anterior to each spiracle. Macrotubular ducts scattered across head through to abdominal segment VII, tending to form transverse bands from mesothorax through abdominal segment VII but with fewer on abdominal segments IV–VI, and absent on abdominal segment VIII.

Etymology. The species name *gracilipilus* is composed of *gracili* (Latin) = gracile or slender and *pilus* (Latin) = hair, the name referring to gracile truncate setae that adorn its dorsum.

Diagnostic features. *Dactylopius gracilipilus* **sp. nov.** is most similar in appearance to *D. tomentosus*, but they are easily distinguish by (character-states on *D. tomentosus* in brackets): (i) presence of abundant simple pores (absent or rare), (ii) clusters of wide-rimmed quinquelocular pores with 10 or more pores abundant (large clusters of wide-rimmed pores uncommon), and (iii) truncate setae with parallel sides forming medial longitudinal rows, each seta 1.5–2 times as long as wide (setae in medial longitudinal row each less than 1.5 times as long as wide).

Remarks. Both *D. gracilipilus* and *D. tomentosus* infest members of the tribe Cylindropuntieae *sensu* Wallace and Dickie (2002) (Cactaceae). This might suggest a close affinity between these two species but *D. gracilipilus* appears to be restricted to *Corynopuntia,* whereas *D. tomentosus* has always been found on *Cylindropuntia* spp.,

even when *Corynopuntia* plants are growing about a meter away and are infested with *D. gracilipilus*. Only a very small portion of desert pavement habitat containing *Corynopuntia* has been explored for *Dactylopius*, so there may be other localities in the Chihuahuan, Sonoran, and Mojave Deserts where *D. gracilipilus*, or even other undiscovered species of *Dactylopius*, might be found.

Mathenge *et al*. 2009 showed that, under the conditions of their study, collections of *D. tomentosus* could be transferred to other *Cylindropuntia* spp. These authors found that *D. tomentosus* collections from *Cy. fulgida fulgida* (Engelm.) F.M. Knuth performed poorly on the host-plant species on which they were not native, and proposed a 'red queen' or 'new association' type hypothesis for their poor performance (Van Valen 1973; Hokkanen & Pimentel 1984, 1989). Additionally, they hypothesized that *Cy. fulgida fulgida* plants have no innate immunity to *D. tomentosus* biotypes originally collected on *Cy. imbricata* (DC.) F. Knuth and *Cy. cholla* (F.A.C. Webber) F.M. Knuth, which they used to explain the superior performance of biotypes collected from the latter two host plants on *Cy. fulgida fulgida*.

There are many alternative host-plant specificity hypotheses (Janz 2011). Hypotheses incorporating population genetic theory (Normark & Johnson 2011) suggest that, overtime, isolated populations accumulate mutations on detoxification genes for host-plants that do not occur in their isolated range. This is considered to be a plausible alternative hypothesis for the formation of biotypes, as it would also explain why isolated populations from different biotypes collected in Mexico (*D. tomentosus* 'tunicata' and 'rosea' biotypes) had such poor ability to reproduce on *Cy. fulgida fulgida*.

Evidence presented by Mathenge *et al*. 2009 clearly shows that biotypes do exist in *Dactylopius* even if the evolutionary processes are not clear at present. Additionally, mitochondrial and nuclear DNA gene phylogenies reconstructed by the authors (*in prep*), including *D. tomentosus* specimens from much of its known geographic distribution and from similar locations to those used by Mathenge *et al*. 2009, such as the 'cholla' biotype, clearly define *D. gracilipilus* and *D. tomentosus* as separate monophyletic groups. Within *D. tomentosus*, there is geographic structuring largely defined by different desert biomes (*in prep*). It seems plausible that biotypes represent geographically isolated populations that receive a negligible amount of gene flow from other populations. Allopatry between different populations of the common ancestor of *D. tomentosus* and *D. gracilipilus* may have resulted in genetic drift in detoxification genes leading to host specificity and eventual speciation after extended periods of allopatry. *Corynopuntia* and *Cylindropuntia* can have different alkaloid compounds (Meyer *et al*. 1980), and this difference may act as part of a reinforcement mechanism between *D. tomentosus* and *D. gracilipilus*.

References

Ben-Dov, Y. & Marotta, S. (2001) Taxonomy and family placement of *Coccus bassi* Targioni Tozzetti, 1867 (Hemiptera: Coccoidea). *Phytoparasitica*, 29, 169–170.

Benson, L. (1982) *The cacti of the United States and Canada*. Stanford University Press, Stanford, 1044pp.

Chávez-Moreno, C.K., Tecante, A. & Casas, A. (2009) The *Opuntia* (Cactaceae) and *Dactylopius* (Hemiptera: Dactylopiidae) in Mexico: a historical perspective of use, interaction and distribution. *Biodiversity and Conservation*, 18, 3337–3355.

Chávez-Moreno, C.K., Tecante, A., Casas, A. & Claps L.E. (2011) Distribution and habitat in Mexico of *Dactylopius* Costa (Hemiptera: Dactylopiidae) and their cacti hosts (Cactaceae: Opuntioideae). *Neotropical Entomology*, 40, 62–71.

Claps, L.E. & de Haro, M.E. (2001) Coccoidea (Insecta: Hemiptera) associated with Cactaceae in Argentina. *Journal of the Professional Association for the Cactus Development*. 4, 77–83.

Costa, O.G. (1835) *Nuove osservazioni intorno alle cocciniglie ed ai loro pretesi maschi*. F. Fernandes, Napoli, Italy, 24pp.

De Lotto, G. (1974) On the status and identity of the cochineal insects (Homoptera: Coccidea: Dactylopiidae). *Journal of the Entomological Society of South Africa*, 37, 167–193.

FAO (2003) *Trade and Sustainable Forest Management – Impacts and Interactions*. Forest Products and Economics Division Food and Agriculture Organization (FAO), Rome, 303pp.

Forster, B., Van De Ville, D., Berent, J., Sage, D. & Unser, M. (2004) Complex wavelets for extended depth-of-field: a new method for the fusion of multichannel microscopy images. *Microscopy Research and Technique* 65, 33–42. Program available from: http://bigwww.epfl.ch/demo/edf/ (accessed 5 January 2012).

Githure, C.W., Zimmermann, H.G. & Hoffmann, J.H. (1999) Host specificity of biotypes of *Dactylopius opuntiae* (Cockerell) (Hemiptera: Dactylopiidae): prospects for biological control of *Opuntia stricta* (Haworth) Haworth (Cactaceae) in Africa. *African Entomology,* 7, 43–48.

Griffith, M.P. (2002) *Grusonia pulchella* classification and its impacts on the genus *Grusonia*: morpholological and molecular evidence. *Haseltonia,* 9, 86–93.

Hokkanen, H.M.T. & Pimentel, D. (1984) New approach for selecting biological control agents. *Canadian Entomologist*, 116, 1109–1121.

Hokkanen, H.M.T. & Pimentel, D. (1989) New associations in biological control: theory and practice. *Canadian Entomologist,* 121, 829–840.

Hosking, J.R., Sullivan, P.R. & Welsby, S.M. (1994) Biological control of *Opuntia stricta* (Haw.) Haw. var. *stricta* using *Dactylopius opuntiae* (Cockerell) in an area of New South Wales, Australia, where *Cactoblastus cactorum* (Berg) is not a successful biological control agent. *Agriculture Ecosystems and Environment*, 48, 242–255.

Janz, N. (2011) Ehrlich and Raven Revisited: Mechanisms Underlying Codiversification of Plants and Enemies. *Annual Review of Ecology, Evolution, and Systematics*, 47, 71–89.

Kondo, T., Hardy, N., Cook, L. & Gullan, P. (2006) Description of two new Genera and species of Eriococcidae (Hemiptera: Coccoidea) from southern South America. *Zootaxa*, 1349, 19–36.

Lopes, E.B., Albuquerque, I.C. , Brito, C.H. & Luna Batista, J. (2009) Velocidade de infestação e dispersão de *Dactylopius opuntiae* Cockerell, 1896 em palma gigante na Paraíba. *Engenharia Ambiental - Espír ito Santo do Pinhal*, 6, 196–205.

Mathenge, C.W., Holford, P., Hoffmann, J.H., Zimmermann, H.G., Spooner-Hart, R. & Beattie, G.A. (2009) Distinguishing suitable biotypes of *Dactylopius tomentosus* (Hemiptera: Dactylopiidae) for biological control of *Cylindropuntia fulgida* var. *fulgida* (Caryophyllaes: Cactaceae) in South Africa. *Bulletin of Entomological Research*, 99, 619–627.

Meyer, B.N., Mohamed, Y.A.H. & McLaughlin, J.L. (1980) b-Phenethylamines from the cactus genus *Opuntia*. *Phytochemistry*, 19, 719–720.

Normark, B. & Johnson, N.A. (2011) Niche explosion. *Genetica*, 139, 551–564.

Perez Guerra, G. & Kosztarab, M. (1992) Biosystematics of the family Dactylopiidae (Homoptera: Coccinea) with emphasis on the life cycle of *Dactylopius coccus* Costa. *Bulletin of the Virginia Agricultural Experiment Station Bulletin* 92, 1–90.

Portillo, L. & Zimmermann, H.G. (2008) *Dactylopius opuntiae*: una especie en peligro de extension. pp. 69–73. (Eds) Llanderal, C., Zetina, D.H., Vigueras, A.L. & Portillo, L. *In. Grana Cochinilla y Colorantes Naturales*. Colegio de Postgraduados Montecillo, Edo. de Mexico, Mexico, 124pp.

Ralston, B.E. & Hilsenbeck, R.A. (1992) *Opuntia densispina* (Cactaceae): a new club cholla from the Big Bend region of Texas. *Madrono*, 39, 281–284.

Rasband, W.S. (1997) *ImageJ*. U. S. National Institutes of Health, Bethesda, Maryland, USA. Available from: http://imagej.nih.gov/ij/ (accessed 5 January 2012).

Rodriguez, L.C., Pascual, U. (2004) Land clearance and social capital in mountain agro-ecosystems: the case of Opuntia scrubland in Ayacucho, Peru. *Ecological Economics*, 49, 243–252.

Santos, P. de S., da Silva, M.A.Q., Monteiro, A.C. & Gava, C.A.T. (2011) Improving photoprotection of *Beauveria bassiana* conidia for biological control of the cactus pest *Dactylopius opuntiae* in the semiarid region northeast of Brazil. *Biocontrol Science and Technology*, 21, 893–902.

Singh, S.P. (2004) *Some Success Stories in Classical Biological Control of Agricultural Pests in India*. Asia-Pacific Association of Agricultural Research Institutions (APAARI) FAO-RAP, Bangkok, 73pp.

USDA (2011) *Instructions for slide-mounting scales & mealybugs*. Systematic Entomology Laboratory, United States Department of Agriculture. 2pp. Available from: http://www.ars.usda.gov/SP2UserFiles/Place/12754100/IDService/scaleslides.pdf (accessed 5 January 2012).

Van Valen (1973) A new evolutionary law. *Evolutionary Theory*, 1, 1–30.

Wallace, R.S. & Dickie, S.L. (2002) Systematic implications of chloroplast DNA sequence variation in subfam. Opuntioideae (Cactaceae). *Succulent Plant Research*, 6, 9–24.

Williams, D.J. & Watson G.W. (1987) *The scale insects of the tropical South Pacific region part 2 the mealybugs (Pseudococcidae)*. C.A.B. International, Oxon, Wallingford, 260 pp.

Zimmermann, H., Bloem, S. & Klein, H. (2004) *Biology, History, Threat Surveillance and Control of the Cactus Moth*, Cactoblastis cactorum. Joint FAO/IAEA Programme, IAEA, Vienna, 40pp.