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Full Identification of Phytophagous Turfgrass Mite Species

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Summary

Phytophagous mites were first identified as a problem in warm-season turfgrasses in Australia more than 80 years ago. Despite this, it was still not clear which mite species were causing damage and to which turfgrass species, although there had long been an underlying assumption (based mainly on overseas literature) that mites of the family Eriophyidae were the main cause of the distorted growth symptoms frequently seen and attributed to mite damage. An Australia-wide survey conducted during the 2010/11 growing season (TU10002 – McMaugh et al., 2011) followed by opportunistic sampling over the next 5 years found two eriophyid (*Aceria cynodoniensis, Abacarus cynodonsis*) and one tenuipalpid species (*Dolichotetranychus australianus*) in relation to mite damage on *Cynodon dactylon* and *C. dactylon X transvaalensis* (bermudagrass). A new tarsonemid mite species, *Steneotarsonemus hippodromus*, was described from *Pennisetum clandestinum* (kikuyugrass) and was found extensively on both turf and pasture plantings of kikuyugrass. Grass-webbing tetranychid mites (*Oligonychus* spp.) also occasionally affect these and a wide range of other warm-season grasses non-selectively. The putative origin, distribution, symptoms and implications of these mite species for turf producers and facility managers are discussed.

Keywords

Aceria, *Dolichotetranychus*, *Steneotarsonemus*, *Oligonychus*, *Cynodon* spp., green couchgrass, *Pennisetum clandestinum*, kikuyugrass

Introduction

Warm-season species dominate turfgrass use in Australia. These accounted for approximately 85% of production turfgrass in a national survey conducted in 2006 (Haydu et al., 2008; Aldous et al., 2009). Within the warm-season turfgrasses, the ‘big three’ – *Cynodon* spp. (green couchgrasses – 44%), *Stenotaphrum secundatum* (buffalograss – 32%), and *Pennisetum clandestinum* (kikuyugrass - c. 15%) – dominate the production sector and collectively represent around 90% of warm-season turfgrass sales. While other well adapted and widely naturalized species reduce their contribution in established turf areas, any pest or pest group that affects one or more of the ‘big three’ warm-season turfgrasses clearly has important implications for the Australian turfgrass industry, both at the production and at the facility management levels.

In this context, the effects of mites on warm-season turfgrasses in Australia has long been a contentious, misunderstood, confused and poorly documented topic. Eriophyid mites were first reported on *Cynodon dactylon* in Western Australia over 80 years ago by Newman (1934) and tentatively identified as *Eriophyes tenuis*. Subsequently, Gibson (1967) in New South Wales made what has since been credited as the first report from Australia of eriophyid mite on *C. dactylon*; this was identified by H.H. Keifer as *Aceria neocynodonis,* now *Ac. cynodoniensis* (Acari: Eriophyoidea: Eriophyidae), which is the ‘bermudagrass mite’ reported from the USA (e.g. Keifer, 1960; Keifer et al., 1982) as causing damage to *C. dactylon* and *C. dactylon x transvaalensis*.

Prior to this, Womersley (1943) described a flat-mite, *Dolichotetranychus australianus* (Acari: Tetranychoidea: Tenuipalpidae), from an infestation found on a *C. dactylon* bowls green at Gayndah in southern Queensland. From references in the extension and popular literature by Champ (1961) and Judy McMaugh (1986), it would appear that this second mite species found on *C. dactylon* was reasonably well known for a time.

Nowadays, however, the only mite mentioned in the recent turf literature or taught in educational courses in Australia prior to the present work has almost universally been assumed to be *Aceria cynodoniensis*, based on American literature for this species over the past 40 years or so. Moreover, because mites are extremely small and very difficult to see in dissected plant material without adequate magnification, especially eriophyid mites which are almost colourless, their presence in the field is almost always determined indirectly by the visual symptoms they cause in affected plants

Brief mention of unnamed tarsonemid mites (Acari: Tarsonemidae) on *Pennisetum clandestinum* was made by Allen (1967). However, while additional samples had been collected and stored, there was no further information on these mites or their identity until the present work was undertaken.

Mite infestations distort the shoots and lead to slower turfgrass growth through poor lateral stolon extension and a subsequent lack of turf strength through reduced matting of stolons and poor root development. In the case of production turf, this results in sod breaking up or tearing on the harvest conveyer and, hence, loss of harvested product which anecdotally can reach 30% or more. Where mite infestations are lighter allowing intact turf rolls to be harvested, this then transfers the problem to the buyer of that turf. Managers of established turf facilities (sports fields, parks, golf courses, bowls greens, race tracks, etc) face two major issues in the event of a mite outbreak at their facility: firstly, reduced use due to poorer wear resistance allied with the extremely slow recovery from wear of the mite-affected turf; and, secondly, the poor quality and uneven nature of the turf surface through distortion and thinning caused by mites.

Despite the significance of the damage that can be caused by mites to turfgrass surfaces, their presence is often not recognized, which leads to ineffective solutions to other perceived problems being implemented. Moreover, it has not been clear exactly which mite species and how many different mite species infest the various warm-season turfgrasses. Without proper documentation of the actual mite species involved with each of the different turfgrasses, effective control measures for all situations cannot be devised. This was the catalyst for a national survey in 2010/11 (TU10002 - McMaugh et al., 2011) as the starting point to provide definitive answers, and was followed by further sampling through to 2015/16 for detailed taxonomic studies. A preliminary account of this work with identifications down to genus level was presented at the 3rd International Horticulture Congress in 2014, and included additional minor grass species (McMaugh et al., 2016 – see Appendix 1). This report covers only the two major turfgrass groups, *Cynodon* spp. and *P. clandestinum* for which detailed taxonomic studies have now been completed on the phytophagous mites found. We note, however, that further investigations are warranted in relation to the mites associated with *Zoysia* spp., but these studies are potentially extremely time-consuming and have been deferred also pending additional samples and specimens (*Dolichotetranychus*) and, in the case of *Aceria*, detailed morphological comparisons with similar species from other warm-season turfgrasses.

Methodology

In the course of our initial one-year survey during the 2010/11 growing season, 68 samples from *Cynodon* spp. and *P. clandestinum* from 48 sites were examined for the presence of mites in the laboratory at Orange, New South Wales (NSW). Sampling was conducted in all Australian states and territories (with the exception of Tasmania and the Northern Territory). Because mites tend to be spread unevenly over an area with “hot spots” showing where the infestation is concentrated, samples were taken when and from where visual symptoms suggestive of mite damage were seen, rather than trying to collect at random across a particular site. GPS coordinates for each collection site were later confirmed on Google Earth using the physical address, and photographs were taken of the damage observed. Field samples were wrapped in damp paper, placed in zip-sealed plastic bags, and refrigerated prior to forwarding by Express Post to the laboratory. Overall, samples were collected from turf production farms and other country sites (38%), urban open space including parks, roadsides and lawns (40%), sports (13%) and research facilities (9%).

On arrival in the laboratory, plant samples were placed separately into screw-capped plastic containers with 70% ethanol and shaken for approximately 2 min to extract mites hidden in the foliage; usually, the plant material was partially macerated beforehand to assist in the release of mites. Samples were then vacuum-filtered. For this process to be effective, it was essential to limit the soil contamination in the collected samples to prevent mites from being obscured during examination. Filtered samples were then examined under a stereomicroscope and mites identified to family and genus level.

Representative mite specimens were then picked off and mounted on microscope slides in Hoyer’s medium (Krantz, 1978) for further detailed examination under a compound microscope equipped with phase contrast (Olympus BX50). Some fresh samples were also dissected directly under a stereomicroscope (Wild M5, 50X magnification) for examination, which facilitated photographs of the mites and their eggs.

Subsequent to our initial 2010/11 survey, a further 194 samples of *Cynodon* spp. (124) and *P. clandestinum* (70) from 126 sites, 98 of which were new collection sites, have been examined through until 2015/16, mostly in specialist acarology laboratories in South Brisbane, Queensland (QLD) and Orange (NSW). There was also some repeat sampling at older collection sites over time. Extraction methodology was similar to that described above, though greater use was also made of direct examination through dissection of fresh samples under a stereomicroscope. Any variations in methodology are detailed below.

Identifications of eriophyoid mites to species level were made by using the keys provided by Amrine et al. (2003) in addition to the published descriptions of *Aceria cynodoniensis* by Sayed (1946) and *Aceria neocynodoniensis* by Keifer (1960). The identification of *Abacarus cynodonis* Abou-Awad & Nasr, 1983 was based on the original description and illustrations in addition to publications by Smith Meyer (1989) and Wang et al. (2014), which reported the presence of this species from Africa and Saudi Arabia, respectively.

The hypothesis that *D. summersi* and *D. australianus* represent the same species was tested by examining type specimens of *D. summersi* and type specimens, historic collections and fresh material of *D. australianus*. New specimens of *D. australianus* were removed from under sheaths of infested

Cynodon spp., killed in 75% ethanol, mounted in Hoyer's medium, and examined at a magnification of 1000× using a Nikon Eclipse 80i microscope equipped with Nomarski optics and a drawing tube. Specimens for measurement were selected after examining all available material and choosing from this a subsample of good-quality specimens from several localities and representing different body sizes. Further details regarding measurements taken are included in the published paper (Appendix 2).

Tarsonemid mites were collected from *P. clandestinum* by stripping leaf blades and sheaths, and shaking them for one minute in 50 mL of 75% ethanol, which was then drained through a sieve into a petri dish, allowed to settle, and examined. Some mites were also removed directly from grass, with the aid of a stereomicroscope, where they formed small colonies close to the node, often just under the sheath. Specimens were cleared in Nesbitt's fluid, slide-mounted in Hoyer's medium and examined with a Nikon Eclipse 80i microscope as described above. A subsample of good-quality specimens from several localities and representing different body sizes were selected for measurement after examining all available material and choosing from this. Further details regarding measurements taken are included in the published paper (Appendix 3). Specimens for scanning electron microscopy were dehydrated with Hexamethyldisilazane, sputter-coated with gold, and examined in a Hitachi TM-1000 Tabletop microscope.

Outputs

Four major journal papers, two short communications and three extension articles in trade magazines and conferences have been published or submitted for publication. These are listed in approximate chronological order below.

Loch, D. 2015. Couch mite...which mite? *Australian Turfgrass Management* **17**(3), 56-59.

Loch, D. 2015-16. Couch mite...which mite. *The Telegrass (Sports Turf Association QLD)* 17, 19-23.

McMaugh, P., Knihinicki, D.K., Seeman, O.D., Loch, D.S. 2016. Preliminary assessment of mite infestations on warm-season turfgrasses in Australia. *Acta Horticulturae* (in press).

Seeman, O.D., Loch, D.S., McMaugh, P.E., 2016. Redescription of *Dolichotetranychus australianus* (Trombidiformes: Tenuipalpidae), a pest of bermudagrass *Cynodon dactylon* (Poaceae). *International Journal of Acarology* **42,** 193-205.

Seeman, O.D., Loch, D.S., Knihinicki, D., McMaugh, P.E., 2016. A new species of *Steneotarsonemus* (Acari: Tarsonemidae) from Kikuyu Grass, *Pennisetum clandestinum* (Poaceae), in Australia. *Systematic and Applied Acarology* **21**, 889-906.

Knihinicki, D.K., Seeman, O.D., McMaugh, P.E., Loch, D.S., 2017. Phytophagous mite species affecting *Cynodon* spp. (bermudagrasses) and *Pennisetum clandestinum* Hochst. ex Chiov. (kikuyugrass) in Australia. *Crop Science* (submitted).

Loch, D.S., Seeman, O.D. 2017. Incidence and distribution of mite species across a collection of *Cynodon* spp. (bermudagrass) genotypes growing in subtropical Australia. *International Turfgrass Society Research Journal* **13** (in preparation).

Akamine, H., Seeman, O.D., Loch, D.S. 2017. *Dolichotetranychus zoysiae* Ehara, a pest of zoysiagrass turf in Okinawa Island (Japan). *International Turfgrass Society Research Journal* **13** (in preparation).

Outcomes

Methodology

Phytophagous mites were extracted from 43% of the 68 samples in the initial 2010/11 survey. With improved sampling and handling together with greater experience in recognising the external symptoms of mite infestations, phytophagous mites were successfully recovered from 76% of the 194 samples examined subsequently (95% of *Cynodon* spp., 76% of *P. clandestinum* samples, respectively).

Cynodon spp. (Green Couchgrass)

Two main mites were identified from *Cynodon* spp.: *Dolichotetranychus australianus* (Seeman et al., 2016a – see Appendix 2) and *Aceria cynodoniensis* (Knichinicki et al., 2016 – see Appendix 3). For *C. dactylon* and *C. dactylon x C. transvaalensis* collectively, the number of survey samples containing phytophagous mites was almost evenly divided between *Ac. cynodoniensis* (Eriophyidae) and *D. australianus* (Tenuipalpidae), 8 and 9 samples respectively from a total of 40. A similar trend continued in subsequent sampling, with mixed tenuipalpid-eriophyoid populations found in 31 cases; note also the co-habitation of these two species in Egypt which was reported by Sayed (1946). These co-infestations were usually dominated by one or other mite species (9 by *Ac. cynodoniensis*, 15 by *D. australianus*). It is also perhaps noteworthy that neither mite species was recorded in our work on straight *C. transvaalensis*, nor are there any reports of any such infestations in the literature.

The visual symptoms (i.e. the distorted growths, or galls) caused by infestations of *Ac. cynodoniensis* and *D. australianus* are subtly different (Plates 1 and 2, respectively). Witch's brooms (rosetted growths at stolon nodes – see also Keifer et al., 1982) and poor stolon root development are typical of *Ac. cynodoniensis* infestations, which tend to be concentrated more along the edges rather than being spread across an area. At the same time, individual growths within an *Ac. cynodoniensis* witch's broom become shortened with leaves greatly reduced in length, thickened and flattened laterally to give a 'pinetree' effect. *D. australianus* on the other hand, produces a characteristic thinning and weakening of the stand, usually concentrated in patches, but frequently spread across an infested area rather than being prevalent along the margins. There is markedly less proliferation of distorted growths at stolon nodes (i.e. no strong witch's brooming), and these pinetree-like growths are slightly more thickened and rounded with even shorter leaves than for *Ac. cynodoniensis*. *D. australianus* can also persist in some much older, elongated pinetree-like growths (e.g. Plate 2(e)), though not as prevalent as in younger, fresher growths. In the case of mixed *Aceria-Dolichotetranychus* populations, the external symptoms tended to follow the most dominant species.

Populations of *Ac. cynodoniensis* and *D. australianus* could be exceptionally high in massively distorted growths, providing those aberrant structures had not yet been browned or killed by the mites. Counting each individual mite present was impractical, but 11 samples had well over 10,000 mites (5 with *Ac. cynodoniensis*, 6 with *D. australianus*). A further eight samples had an estimated 1,000-10,000 eriophyoid mites and six samples had a similar number of flat mites; of these only one sample had both > 1,000 eriophyoid and flat mites.

During our initial survey, a single specimen of *Abacarus cynodonis* (Eriophyidae) was collected from Perth, Western Australia (WA). This has since been determined as a previously unrecorded mite species in Australia. Two further collections of this species were subsequently located among national records and stored specimens, one from Sydney (NSW) in 2009 and the other from Townsville (QLD) in 2011.

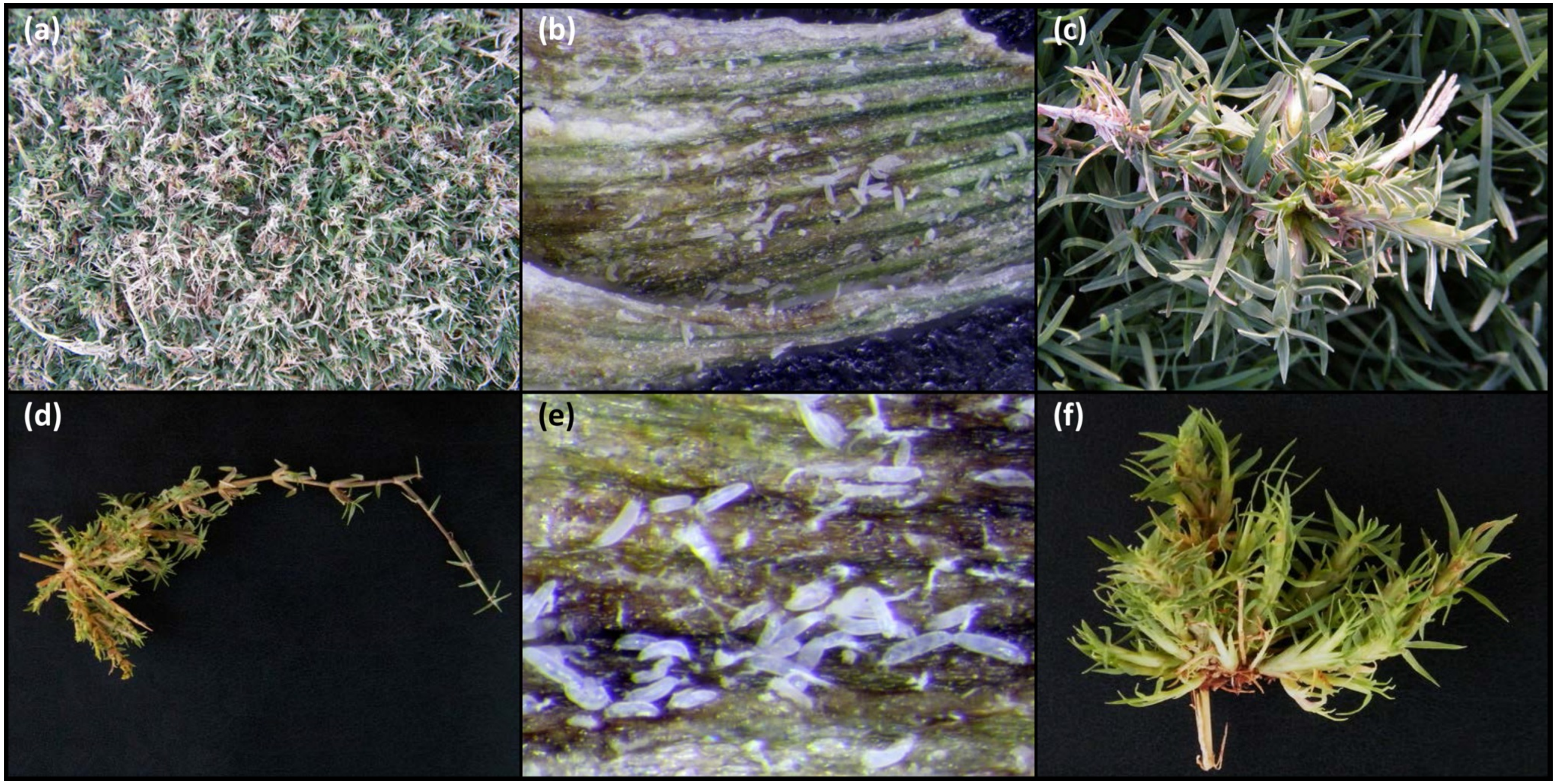

Plate 1. *Aceria cynodoniensis* damage to *Cynodon* spp.: (a) and (c), infested swards showing 'witches brooming' (rosetting) of distorted growths in situ; (b) and (e), mites and eggs found under leaf sheath; (d) and (f), close-up views of witches brooms and distorted shoots.

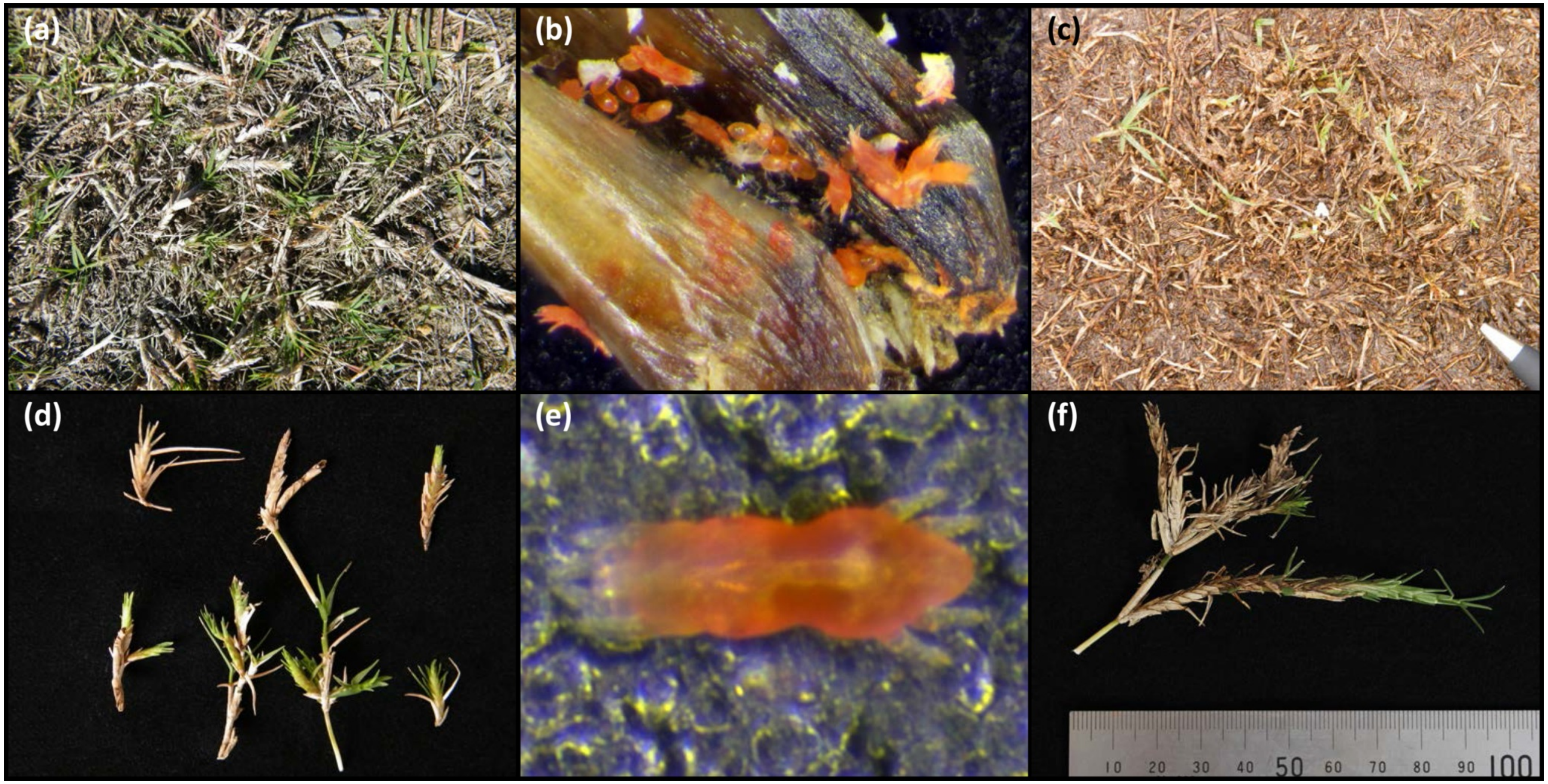

Plate 2. *Dolichotetranychus australianus* damage to *Cynodon* spp.: (a), weak sward growth showing 'pinetree-like' growths without rosetting; (b), mites and eggs found under a leaf sheath; (c), death of sward due to severe mite infestation; (d), close-up view of pinetree like growths; (e), female *Dolichotetranychus australianus* mite; (f), elongated pinetree-like growth (8-cm long) found in an old mite infestation.

Pennisetum clandestinum (Kikuyugrass)

Mites from *P. clandestinum* in Australia were determined to be a new species of *Steneotarsonemus* (Tarsonemidae) from the subgenus *Steneotarsonemoides*. This species was recently described as *Steneotarsonemus hippodromus* by Seeman et al. (2016b) – see Appendix 4. Members of this genus are phytophagous and several species are pests (e.g. Hummel et al., 2009). Note that, superficially, *Steneotarsonemus* and *Dolichotetranychus* mites can appear similar in size and shape when preserved plant material is quickly scanned under the stereomicroscope, particularly since the characteristic reddish colour of the *D. australianus* mites can be lost through storage in 70% ethanol. This problem may have accounted for some apparent misidentifications during our initial survey (McMaugh et al., 2011). Subsequently, however, we recorded adult female *D. australianus* mites on *P. clandestinum* on only two occasions out of a total of 53 samples (post-survey 2011-2016) with mites present; this occurred when *P. clandestinum* was growing amongst, or in close proximity to, infested *C. dactylon*, and tarsonemid mites were also present on both occasions (Seeman et al., 2016a; McMaugh et al., 2016). However, rather than being indicative of *P. clandestinum* as a preferred host with a resident population, these results are more suggestive of migratory behaviour, with *D. australianus* females moving from the associated *C. dactylon* to establish new colonies under less crowded conditions.

Tarsonemid mites were present in 32 out of 45 samples taken between 2014 and 2016, with an average of 24 ± 4.2 mites per infested sample (range 1-85). The condition of grass explained a significant proportion of the variation ($R^2 = 0.22$, $F(1, 35) = 9.77$, $P < 0.01$), with more mites being found on grass in good condition. Only one mite was found from five samples in poor condition. Perhaps significantly also, the numbers of *S. hippodromus* seen through dissection or recovered by filtration from kikuyugrass were perceived to be appreciably fewer than for *D. australianus* infesting green couchgrass (McMaugh and Loch, 2015; McMaugh et al., 2016).

The visual damage symptoms see in *P. clandestinum* infested with tarsonemid mites varied somewhat between long-cut or uncut grass and short-cut turf (Plate 3). These included poor root development, shortening of the internodes and a proliferation of side shoots along the elevated stolon. Individually, heavily infested shoots were shorter and thicker, giving a clubbed-like appearance along with the possible bleaching of leaves.

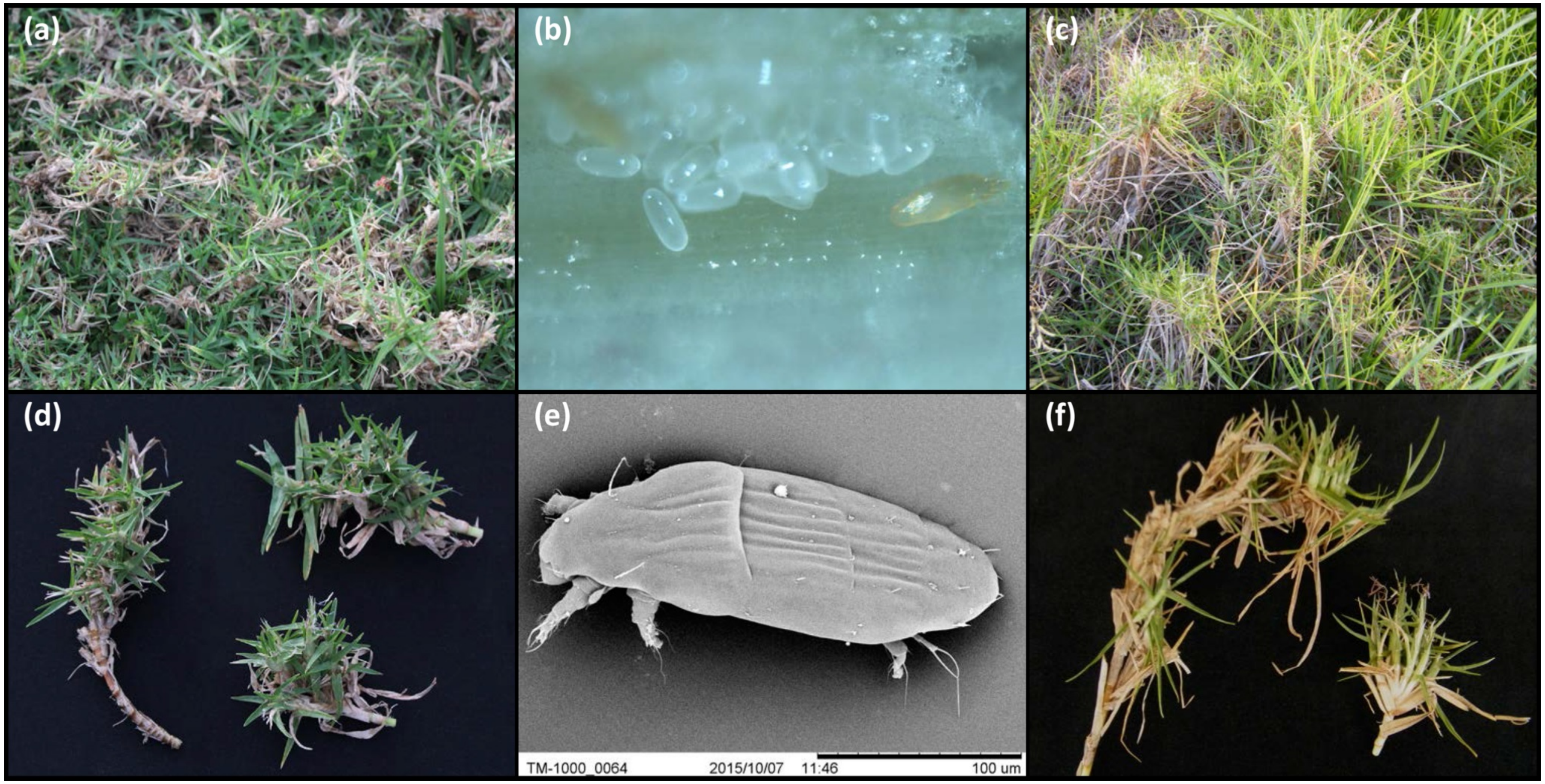

Plate 3. *Steneotarsonemus hippodromus* damage to *Pennisetum clandestinum*: (a) and (d), distorted growth in short-cut turf; (b), female mite and eggs found under a leaf sheath; (c) and (f), distorted growth in ungrazed pasture-length grass; (e), electron micrograph of female *Steneotarsonemus hippodromus* mite.

Evaluation and Discussion

Within the animal kingdom, mites (Subclass: Acari) are second only to the insects in terms of species diversity, but only about 5% of the estimated >1 million mite species have been described so far (Walter, 2006). It is therefore not surprising that a previously undescribed mite species, *S. hippodromus* and previously unrecorded species, *Ab. cynodonis*, are present on turfgrasses in Australia along with other already known species.

Warm-Season Turfgrass Mites in Australia

In Australia, the phytophagous mites recorded on *Cynodon* spp. and *P. clandestinum* turfgrasses to date come from four different families, namely Eriophyidae, Tenuipalpidae, Tarsonemidae and Tetranychidae. The first three families were examined in this study, which asked the question: which species within the specified mite genera is/are responsible for the damage to the various grasses? The Tetranychidae were rare throughout our study, but are also discussed briefly below by way of completeness.

Essentially, all of the mite species from the three main groups studied are found Australia-wide: wherever their host species will grow (Plate 4). For this reason, *S. hippodromus* is mainly found through the southern half of Australia because *P clandestinum* is only grown in highland areas in northern part of the continent.

1. Eriophyidae. *Aceria cynodoniensis* (bermudagrass mite, couch mite). During our initial 2010/11 survey, eriophyoid mites suspected to be *Ac. cynodoniensis* were extracted from samples of *Cynodon* spp. In Australia, the identity of *Ac. cynodoniensis*, a species of major concern on *Cynodon* spp. worldwide, is now confirmed based on more recently collected samples (including specimens from San Diego, USA) and historic data.

This mite was originally described by Sayed (1946) from infestations found in Egypt. It has since been reported from many other parts of the world, including South Africa (Meyer, 1968; Smith Meyer, 1981a, 1981b), the USA (initially as *Ac. neocynodonis*), Zimbabwe (Goldsmid 1964), Greece (Kapaxidi et al., 2008) and Saudi Arabia (Wang et al., 2014). Although Gibson's (1967) collection from NSW is regarded as the first official record of this species from Australia, as mentioned earlier, there is a much earlier record in the literature by Newman (1934) whereby the symptoms of a similar witch's brooming effect on *C. dactylon* in Western Australia are described. In USA, it occurs across all of the southern states including Arizona, California (Keifer, 1960; Tuttle and Butler, 1961), Florida (Denmark, 1964; Johnson, 1975), Georgia (Davis, 1964; Barke and Davis, 1971), Nevada, New Mexico, Oklahoma and Texas (Reinert, 1982; Reinert et al., 1978, 2004, 2008). However, it is not listed in the checklist prepared by Xue and Zhang (2009) as having been recorded in South-East Asia.

The main plant host for *Ac. cynodoniensis* is *C. dactylon* but it has also been recorded widely on *C. dactylon x transvaalensis* and on *Cynodon incompletus* (Meyer, 1968; Smith Meyer, 1981a; Wang et al., 2014), which was supported by one sample from *C. incompletus* in our current work. Smith Meyer (1981a, 1981b) also reported *Ac. cynodoniensis* as having been recorded on *P. clandestinum* in South Africa, though this must be regarded as doubtful unless independently verified. It inhabits the terminal leaf sheaths of the grass which leads to profound stunting and a witch's brooming effect followed by plant decline.

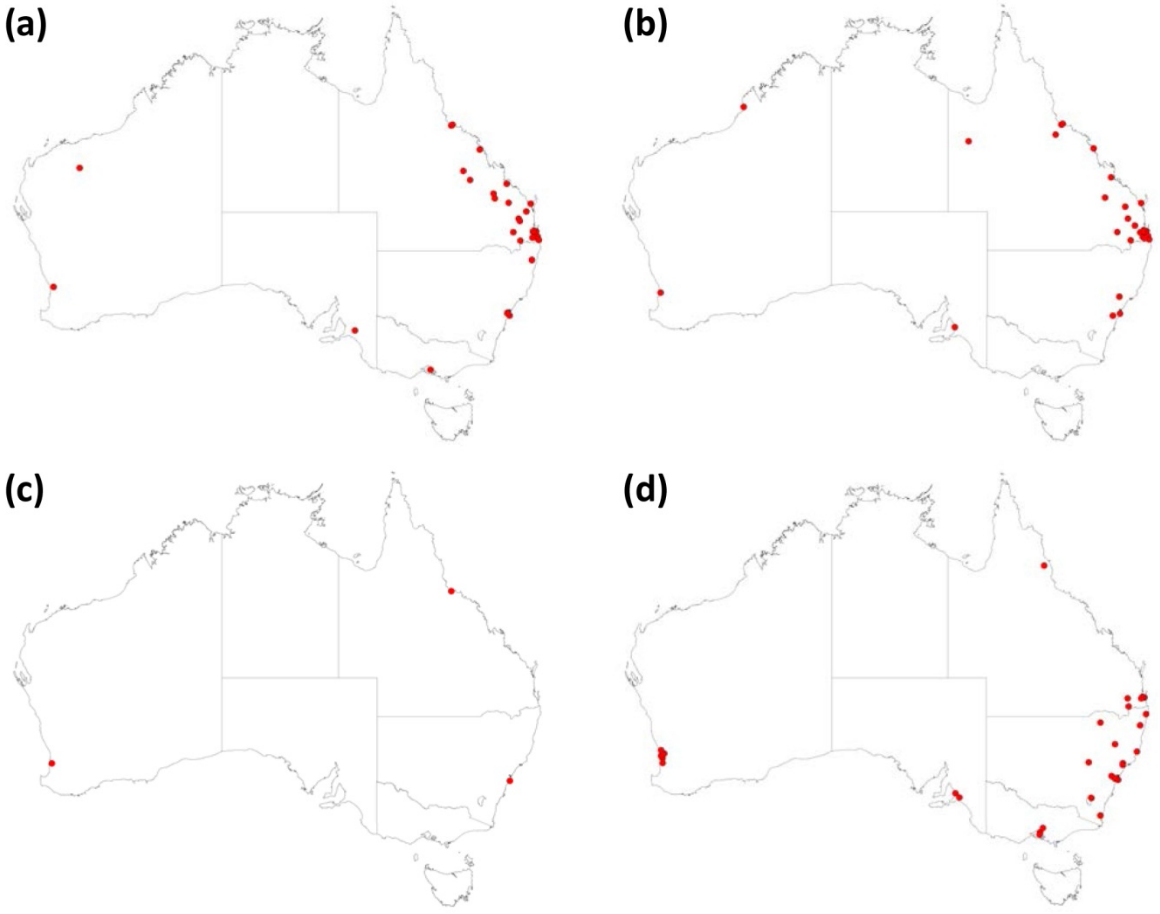

Plate 4. Australian distribution maps based on locations for current and historic samples of (a) *Aceria cynodoniensis*, (b) *Dolichotetranychus australianus*, (c) *Abacarus cynodonis*, and (d) *Steneotarsonemus hippodromus*.

Early acarologists such as Butler (1963) believed that the bermudagrass mite, *Ac. cynodoniensis*, is native to Africa. More recently, suggestions in the American literature (e.g. Reinert, 1982; Williamson et al., 2013) have implied that *Ac. cynodoniensis* is probably native to Australia. However, without any supporting evidence in such publications, this does not fit well with the presumed centre of origin for the grass species, *C. dactylon*, which is located in the Middle East with a widespread distribution throughout Africa (Harlan and de Wet, 1969), nor with the fact that most (if not all) *Cynodon* genotypes in Australia are derived from recent imports (Langdon, 1954; Jewell et al., 2012).

The genus name *Aceria* was initially confused with *Eriophyes* in the literature following a proposal by Newkirk and Keifer (1971) to revise the type species designation for the latter, which was then corrected by the International Commission on Zoological Nomenclature (Lindquist, 1996). However, in relation to the eriophyoid bermudagrass mite, *Ac. cynodoniensis*, the use of *Eriophyes* instead of *Aceria* has persisted in some American publications, even quite recently (e.g. Williamson et al., 2013).

To date, six different *Aceria* species from *C. dactylon* have been described in the world literature, namely: *Aceria cynodoniensis* (Sayed, 1946), *Aceria neocynodoniensis* Keifer, 1960 (regarded as a junior synonym of *A. cynodoniensis*), *Aceria nilotica* (Abou-Awad and Nasr, 1983); *Aceria dactylonae* (Mohanasundaram, 1983), *Aceria distinctus* (Mitrofanov et al., 1988) and *Aceria cynodonis* (Wilson, 1959). The published morphological descriptions for each of these species are summarised in Table 1. Like *Ac. neocynodoniensis* (junior syn.), It is important to note that some of these other species may also eventually be found to be junior synonyms of *A. cynodoniensis*. However, this would require the subsequent collection and careful taxonomic assessment of additional actual specimens since the original type material is unlikely to be available for study. It is also possible that all of these species are valid. However, with the use of other diagnostic tools which include both such as molecular and morphological analysis would be useful in conjunction with morphological identification in this regard. Even eriophyoid "species" previously thought to be less host-specific are increasingly being shown to consist of a number of cryptic species (specialised races), each specific to a particular plant species (e.g. Skoracka and Dabert, 2010; Skoracka et al., 2012).

Abacarus cynodonis. The identification of *Abacarus cynodonis* on *C. dactylon* is interesting, and is a new record for Australia. Although not frequently found (or at least identified) and only occurring in low numbers, it shows that this previously unrecorded species has a fairly broad distribution in Australia following its identification in a sample from NSW (Sydney) in 2009, Western Australia (Perth) and Queensland (Townsville) in 2011.

Little is known about the visual symptoms associated with *Ab. cynodonis*. Notes provided with the Townsville collection mention "yellowing of plants", but both *Ac. cynodoniensis* and *D. australianus* also occur at that site and could well account for the shortening of plant nodes and patchy grass cover that were also noted with that collection. According to Abou-Awad and Nasr (1983) in their original description of this species from Egypt, *Ab. cynodonis* mites appear to be vagrants on the leaves preferring the upper surface of leaf blade causing curling of the leaves. Like most eriophyoid mites, it is probably a plant feeder but the damage symptoms, if significant, are yet to be clearly defined. Therefore, this species is not considered to be of current concern despite the fact that the genus *Abacarus* includes economic pests such as *Abacarus hystrix* (cereal rust mite). *Ab. hystrix* occurs in Australia and has a relatively wide host range on cereals and other grasses (including *C. dactylon*), though it may eventually prove to be a complex group of cryptic species targeting different host plant species (Skoracka and Kuczyński, 2006).

Abou-Awad and Nasr (1983) first described *Ab. cynodonis* from bermudagrass in the Sinai Peninsula, Egypt and specimens identified from Australia have been compared with their description in the literature. We note also that the original species name for *Ab. cynodonis* has subsequently been misspelt in the literature as *Abacarus cynodonsis* by Amrine and Stasny (1994) and followed by Wang et al. (2014). Smith Meyer (1989) also recorded this species as being from Africa, although the exact locality and host plant species was were not specified and so she may simply have recognised the initial collection described by Abou-Awad and Nasr (1983). More recently, *Ab. cynodonis* has been identified from Saudi Arabia (Wang et al., 2014) but not on its usual grass host, *C. dactylon*. Rather, it was reportedly found on *Sesuvium portulacastrum*, a coastal plant from the plant family Aizoaceae. Intriguingly, Wang et al. (2014) also reported *Ac. cynodoniensis* from Saudi Arabia for the first time on the same host plant. Given that eriophyoid mites are highly host specific, the finding of *Ab. cynodonis* and *Ac. cynodoniensis* on an unrelated host from a completely different plant family clearly warrants further investigation to validate this report.

2. Tenuipalpidae. The taxonomic history and prior records for *D. australianus* have been discussed in detail by Seeman et al. (2016b). Like *Ac. cynodoniensis*, its native range is likely North Africa and the Middle East, reflecting the native range of its host plant, even though it was first described from bermudagrass in Queensland by Womersley (1943). Prior to our study, *D. australianus* was thought to be found only in the state of Queensland (Smiley and Gerson, 1995), but this species has now been shown to occur Australia-wide on bermudagrass, from Mt Isa and Charters Towers (QLD) to Broome (WA). Intriguingly, the historical records also include a collection reportedly made in Sydney (NSW) in 1939. *D. australianus* also occurs within its presumed native range and through to southern Africa, being found in Egypt (Sayed, 1938, 1946 – as *D. floridanus*; Wafa et al., 1968-69), Iran (Baharloo et al., 2006), Saudi Arabia (Alatawi et al., 2015 – as *D. riyadhensis*), South Africa (Meyer, 1979) and Zimbabwe (Goldsmid, 1962).

3. Tarsonemidae. Tarsonemid mites cover a wide range of feeding behaviour, but those on grasses are probably either fungivorous or phytophagous. While some tarsonemid mites appear not to damage the associated grass plants, the genus *Steneotarsonemus* is regarded as phytophagous. It is therefore significant that *Steneotarsonemus hippodromus* was found in most samples of kikuyugrass (76% post survey), especially those with green leaves showing no discoloration. To date, *S. hippodromus* has been found on no other turfgrass or other grass species. Even though the mite was has only just been described by Seeman et al. (2016b), it has been widespread in Australia and known to Australian acarologists since at least the mid-1960s, being present in Far North Queensland (Upper Barron) and western Sydney at that time (Allen, 1967; historic records). This mite may also have a global distribution, since kikuyugrass is native to east Africa. Significantly in this regard, *S. hippodromus* was also recently discovered in California (Seeman et al., 2016b). Two other tarsonemid mites, *Steneotarsonemus kruseae* and *Tarsonemus scaurus* have also been recorded from kikuyugrass in Costa Rica (Ochoa et al., 1991, 1994; Lin and Zhang, 2002).

Although common in kikuyugrass, mite numbers (maximum of 85 in a sample) were in stark contrast to the tens of thousands of eriophyoid and tenuipalpid mites that infested bermudagrass. Mites were rare in grass with dead or dying plant growth, but were common in green grass, where small colonies established just under the sheath around the node. The plant tissue around these colonies was often discoloured (yellowing of cells), but whether or not this probable feeding damage leads to the distorted growths we observed is unknown, and warrants further attention. In the rice panicle mite, *Steneotarsonemus spinki*, outbreaks result in up to 1,100 mites per tiller (Tseng, 1984) and cause substantial damage to rice. Nevertheless, even small populations of *S. spinki* may be associated with significant damage, depending on the growth stage of the plant (Jiang et al., 1994), although the effects of the mite are often difficult to separate from those of pathogens (Hummel et al., 2009).

4. Tetranychidae. Colonies of grass-webbing mites, namely *Oligonychus araneum* (Davis, 1968) and *Oligonychus digitatus* (Davis, 1966), are occasionally seen on a wide range of warm-season turf and other grasses. These two species often occur together in the same infestation (Gutierrez and Schicha, 1983). Such colonies are obvious even to a casual observer because of the distinctive protective webbing woven over the top of the mites. Only one grass-webbing mite infestation was recorded during the period of our study, though such infestations can be quite numerous in certain years when suitable conditions occur. The two *Oligonychus* species have only been recorded in Australia, with records of apparent and confirmed infestations going back around 80 years (Anon., 1936; Davis, 1968)

Visual Symptoms and diagnosis of mite infestations

In commercial practice, the diagnosis of a mite infestation is almost invariably based on the symptoms seen on the plant host. For this reason, we have provided detailed illustrated descriptions of symptoms seen on different turfgrass hosts and their association with the different groups of mites identified. With experience, the subtle differences in symptoms on green couchgrass give a reasonable guide as to which of the two major mite species, *Ac. cynodoniensis* or *D. australianus*, is likely to be involved (or, at least, which might be the more dominant species). However, not every rosetted or distorted growth on a plant will yield mites (as our results showed). Direct examination through dissection and/or laboratory extraction of plant material is the only reliable way for turf producers and managers to confirm the presence of mites and to determine the possible identity and/or mix of species involved in an infestation. Cheap portable microscope systems that attach to a computer through a USB port are now readily available, making direct examination a more feasible option which would allow the two main genera on bermudagrass, *Aceria* and *Dolichotetranychus*, to be distinguished.

Implications for Chemical Registration

Worldwide, relatively few miticides are registered for turf use (Williamson et al., 2013). A recent search of the Australian Pesticides and Veterinary Medicines Authority's (APVMA's) Public Chemical Registration Information System (PUBCRIS) database showed seven products covering four different active ingredients (all adulticides) registered for mite control in turf – a situation that limits opportunities for rotation of chemical groups to minimise the inevitable risk of resistance developing longer term. Moreover, all of these current registrations are for control of the eriophyoid "couch mite".

However, the effectiveness of different miticides varies according to the group of mites targeted, and the chemicals currently registered for couch mite may not be equally effective on tenuipalpid and tarsonemid mites as shown in recent preliminary work by McMaugh and Loch (2015). Previous trial work leading to registration also appears to have been based on indirect observation of symptoms. In the future, data for registration should be, or should at the very least include sufficient data, based on direct observation of the mites concerned and should cover all of the major species that infest warm-season turfgrasses in Australia, rather than simply claiming the well-known (but by no means the most important) species. For chemical registration purposes, confirmation of mite identifications to species level by a specialist acarologist is to be strongly encouraged for supporting trials, and should really be mandatory.

Table 1. Comparative summary of published morphological data for six *Aceria* species from *Cynodon dactylon* as described in the world literature.

Morphometric Characters	***Aceria cynodoniensis***	***Aceria neocynodoniensis* (junior synonym)**;	***Aceria cynodoniensis***	***Aceria nilotica***	***Aceria dactylonae***	***Aceria distinctus***	***Aceria cynodonis***
Source/Description	Sayed (1946)	Keifer (1960)	Kapaxidi et al. (2008)	Abou-Awad & Nasr (1983)	Mohanasundaram (1983)	Mitrofanov et al. (1988)	Wilson (1959)
Comment	Original description & measurements	Description & measurements by Keifer (1960)	New record from Greece: Partly re-described by measuring Greek specimens				
Similar to other species (as stated by author):	n/s	n/s	n/s	*Aceria muhlenbergiae* Keifer, 1962 ex *Muhlenbergia frondosa* : Ulmaceae	*Aceria bakkeri* Keifer, 1969 ex *Oryza sativa*: Poaceae	*Aceria sorghi* Chan., 1966	n/s
Type host	*Cynodon dactylon*	*Cynodon dactylon* (bermuda grass)	N/A	*Cynodon dactylon*	*Cynodon dactylon*	*Cynodon dactylon*	*Cynodon dactylon*
Damage symptoms	"… Infested plants are usually stunted, leaves much crowded and overlapping….". Inhabiting terminal leaf sheaths causing stunting, witches' broom effect and general decline of the plant.	"..Living in terminal leaf sheets causing stunting, a witches-broom effect and general decline of the grass…" Witches' broom. Rosette type injury.	Feeding & seeking shelter in leaf sheaths; inhibiting growth; sheaths become swollen, closely packed, thickened & bunched at stem node, stunted leaf blades. Affected stems greatly deformed and enlarged nodes & shortened internodes. Especially evident in Spring followed by browning and thinning of grass.	Living under broadened leaf bases. Combined infestation with *Abacarus cynodonis* may cause bending, stunting and twisting of the folded terminal shoots.	Found between the culm and leaf sheath, causing rust.	Free-living vagrant on upper surface of leaves	Twisting of folded terminal shoot & infolding and twisting of expanded leaf blades
Type location	Egypt (lower Egypt and around Cairo)	USA (Brawley, Imperial Country, California		Sinai Peninsula Egypt	Thalavanur, Villuparum Taluk, South Arcot District, Tamil Nadu, India	Near Yalta, Krymskaya Region (Crimea), Ukraine	Moreno, California, Riverside County, USA; coll. May 1954.
Other hosts	n/s	*Pennisetum clandestinum*	*Cynodon dactylon*	Unknown	Unknown	Unknown	Unknown
Other distribution localities (as published in the description)	Egypt		n/s	Unknown	Unknown	Unknown	Unknown
Other known localities	Australia, South Africa; USA (Arizona, California, Florida, Georgia)	See info. (column on left) as for *Aceria cynodoniensis*	Commercial turfgrass nursery in Aliartos (Viotia), Greece	Unknown	Unknown	Unknown	Unknown
Length of body (µm)	210.9 (includes capitulum)	165–210	170–210	195–205	215–220	236	170–211
Width of body	43.8	40	n/s	43–45		53	
Thickness	n/s	n/s	n/s	n/s	45 (? Author may mean width)	?	40–52 thick
Body shape	Cylindrical	Worm-like	n/s	Worm-like	Worm-like	Vermiform	Worm-like
Colour	Whitish	Whitish-cream	n/s	Yellowish-white	White	n/s	White
Length of gnathosoma	19.1; with 2 pairs of setae	23; down-curved	n/s	15; directed down	15; uniformly bent downwards		25; curved down
Length of dorsal genual setae *d* (antapical setae)	n/s	n/s	n/s	n/s	5		n/s
Length of cheliceral stylets	n/s	n/s	n/s	10	n/s		n/s
Length of prodorsal shield	n/s	36	n/s	33	30	34	36

Morphometric Characters	*Aceria cynodoniensis*	*Aceria neocynodoniensis* **(junior synonym)**;	*Aceria cynodoniensis*	*Aceria nilotica*	*Aceria dactylonae*	*Aceria distinctus*	*Aceria cynodonis*
Width of prodorsal shield	n/s	36	n/s	39	30	31	43
Length of setae *sc*	30	45	n/s	36	40, pointing backwards	34	18, projecting backwards
Distance between *sc* tubercles	n/s	23	n/s	17	20; on rear shield margin	17	26; on rear margin
Dorsal shield shape	d.s described as "somewhat conical"	Semicircular anteriorly	n/s	n/s	n/s		
Dorsal shield design	..... with five longitudinal lines and fine sculpture (fig.19)...."	"...Median line present on posterior 2/3; admedian lines sinuate, diverging to the rear; two anterior submedian lines, first sinuate, abruptly curving outward well ahead of dorsal tubercle, a separate line running towards rear of admedian line; second submedian short, curving from anterior margin to about 1/3 on first admedian; line of granulations running to rear margin from second submedian; rear part of shield and sides set with granulations and short dashes...."	Distinctive design of 2 scalloped, parallel ridges running the full lenth of the shield, with a straight, short ridge in between.	Incomplete median line, extending from anterior ¼ to rear margin and broken into three parts, both anterior and posterior part with two branches forming opposite dart-enclosing median line, joined to median by diagonal branches of opposite dart marks, forming nearly hexagon-shaped at about rear ½; submedian line from gnathosoma base, subparallel to admedian, branched at forked line before ½; shield laterally with dots and faint dashes oriented below.	With clear pattern of lines; median line complete; admedians complete; first median curved in anterior end, forked in middle, broken in posterior end; second submedians represented in mid part of shield with a forking anterior end; third & fourth submedians represented by broken lines on sides of shield; sides of shield & shield area with short scorings.	Median line does not pass centre of shield, a short interconnective line between admedian and submedian in medial part of shield.	Central design obsolete; only one submedian line present, arising at posteroventral angle of shield and running anteriorly and dorsally to base of rostrum.
Leg I length	41	30	n/s	23	23; legs with all usual setation.	25 (excluding coxa & empodium)	29.5
Femur I				7	n/s	n/s	n/s
Genu				5, seta 19	n/s	n/s	n/s
Tibia I	n/s	5 (seta 8.5)	n/s	4, seta 6	4, seta 5 at distal 1/3	5	7
Tarsus I	n/s	6	n/s	5, outside seta 15	4; seta present in anterior third of tibia I.	5	7
Solenidion I *ω*	n/s	8 (tapering)	n/s	7, not curved	6	8	7.5, tapering
Empodium I *em*	5-4	n/s	n/s	Shorter than *ω*	n/s	n/s	n/s
Empodium I number of rays	6 -rayed	6 -rayed	6 -rayed	7 -rayed	7 -rayed	8 -rayed	7 -rayed
Leg II length	40	26	n/s	21	21	23	29
Femur II				7	n/s	n/s	n/s
Genu II				5, seta 6	n/s	n/s	n/s
Tibia II	n/s	4.5	n/s	2, no seta	3	3	5.8
Tarsus II	n/s	5	n/s	5, outside seta 19	4	5	7
Solenidion II *ω*	Length n/s; unknobbed	8.5	n/s	7	6	8	6
Empodium II *em*	n/s	n/s	n/s	Shorter than *ω*	n/s	8	n/s
Empodium II number of rays	n/s	n/s	n/s	7 -rayed	n/s; assume 7 -rayed	n/s; assuming 8	n/s; assume 7 -rayed
Length of setae *1b*	6.5	"...First coxal tubercles well ahead of second & a little further apart..."	n/s	Anterior coxae contiguous at about posterior two thirds of short sternal junction line,	n/s	n/s	n/s

Morphometric Characters	***Aceria cynodoniensis***	***Aceria neocynodoniensis* (junior synonym)**;	***Aceria cynodoniensis***	***Aceria nilotica***	***Aceria dactylonae***	***Aceria distinctus***	***Aceria cynodonis***
				two setae on each, coxal seta I a little further apart than setae II & situated at nearly base of sternal fork, design fork in dashes; single seta,			
Distance between tubercules *1b*	n/s	n/s	n/s	n/s	n/s	n/s	n/s
Length of setae *1a*	15	"…..Second coxal tubercles a little ahead of line through third tubercles…."	n/s		n/s	n/s	n/s
Distance between tubercules *1a*	n/s	n/s	n/s		n/s	n/s	n/s
Length of setae *2a*	21	n/s	n/s	Posterior coxae contiguous with anterior ones and each with a seta, 31 long.	n/s	n/s	n/s
Distance between tubercules *2a*	n/s	n/s	n/s	n/s	n/s	n/s	n/s
Coxae ornamentation	Granular striations depicted on illustration of coxigenital region	"….Granular, junction line between anterior coxae parallel by lines of granulations…"	n/s	Coxae ornamented with fine dots, dashes and sinuous lines. Anterior coxae contiguous with anterior ones and each with a single seta, measuring 31 long.	Coxae with all three setiferous tubercles; coxal area with short thick scorings.	n/s	n/s
Sternal line	n/s; present in drawing	n/s; present in drawing	n/s	Present	Present	n/s	n/s
Length of female epigynium	24.6	10.5	n/s	15; bowl-shaped	12	12	19
Width of female epigynium	12.3	18	n/s	17	20	19	14.7
Number of striae on epigynium	8 longitudinal striae (depicted on illustration only).	Approx. 10 narrow longitudinal striae (depicted on illustration & mentioned in text)	11–12 striae, with median striae longer than lateral ones.	10 longitudinal striae	9–10 thickened striae		10 longitudinal striae
Length of setae *3a*	10	8,5	n/s	10	n/s	11	17.6
Distance between tubercules *3a*	n/s	n/s	n/s	n/s	n/s	15	n/s
Length of setae *c2* (lateral setae)	30.5	35	n/s	38	50	38	29.5
Setae *c2* on annulus	n/s. Approx. on 8 behind d.s (based on illustration	On annulus 7 behind d.s	n/s	Above & behind genital seta; surpassing ventral seat I on about 11	On annulus 10	n/s	On annulus 7
Length of setae *d* (ventral setae I)	36.5	32	n/s	36	40	38	33.8
Setae *d* on annulus	Approx. on 23 behind d.s (based on image)	On 21 approx.	n/s	25	On annulus 25	14	On annulus 20
Length of setae *e* (ventral setae II)	6.5	7	n/s	33	35	34	9.5
Setae *e* on annulus	n/s. Approx on 44 behind	On 38 approx.	n/s	44	On annulus 44	32	On annulus 35

Morphometric Characters	*Aceria cynodoniensis*	*Aceria neocynodoniensis* **(junior synonym)**;	*Aceria cynodoniensis*	*Aceria nilotica*	*Aceria dactylonae*	*Aceria distinctus*	*Aceria cynodonis*
	d.s (based on image)						
Length of setae *f* (ventral setae III)	2.4	27	n/s	16	22	19	19
Ventral annulus from rear	4th (based on image)	On 4th from the rear	n/s	On annulus 5 from rear.	On annulus 5 from rear.	55 (counted from posterior edge of cover flap.	On annulus 5 from rear.
Number of opisthosomal annuli	n/s. Approx 68 ventral annuli (counted from behind coxae & based on image)	Approx 65 microtuberculated annuli; microtubercles rounded and ahead of rear annuli margin	n/s. Elliptical microtubercles.	Abdominal thanosome with about 67 rings, completely microtuberculate. Microtubercles evenly spaced along the annuli, similar in all but varying in size, elongate ovally & placed on posterior marging of annular rings.	About 75 annuli, uniformly microtubercular; microtubercles oval in shape at posterior ring margin.	66; microtubercles ellipsoid with tiny posterior conical top	59–63 annuli; dorso-ventrally even; tubercles more numerous in dorsal portion of the annuli, ratio dorso-ventrally approx. 2 to 1. Mocrotubercles small, minutely pointed.
Length of setae *h2*	60	n/s	n/s	60	55		n/s
Length of setae *h1* (accessory setae)	n/s	Present, 2.5	n/s	3	3	3	Present
Male	Not described	Not described	Apparently the empodia (featherclaws) are 5-– rayed I nthe male.	Unknown. Not described	Described as 190–200 long; 45 wide; genitalia 20 wide; genital seta 6 long.	Described as 172 long, 49 wide with 57 dorsal annuli	Unknown/not described.

Recommendations

The work reported here was aimed primarily at elucidating the taxonomy of the main turf mite species involved to facilitate the future registration of chemicals that are better targeted for their control. In addition, this study has also provided a platform on which ecological and biological turf mite studies could be developed in future.

Recommendations flowing from this first objective are:

1. Effective rotational strategies covering all mite species present should be developed. Currently, most users rely on follow-up sprays with the same chemical (usually abamectin), a strategy that will inevitably lead to resistant populations of mites developing longer term; even now, there are unconfirmed reports of abamectin proving less effective on occasions, suggesting that resistance is already starting to develop. The idea behind the release of a diafenthiuron-based product for couch mite control was a welcome move in this direction, but the choice of a chemical that does not appear to be effective on tenuipalpid and tarsonemid mites (McMaugh and Loch, 2015) rather defeats its purpose in relation to these other two important groups of mites.
2. Trial data for miticide registration should be based on extraction and direct observation of the mites concerned, rather than relying on visual symptoms, which do not show visible changes in response to the initial spray application for 6 weeks or more.
3. Trial data for “couch mite” registration should also cover the tenuipalpid mite, which is at least as important in real-world infestations as the well-known eriophyoid couch mite.
4. APVMA registration rules and procedures should be tightened to require confirmation by a specialist acarologist of mite identifications from supporting trials down to species level.
5. Companies with existing registrations for “couch mite” control should be encouraged to conduct supplementary trials to add the tenuipalpid couch mite to their labels.
6. Similarly, companies marketing miticides for turf use should also be encouraged to conduct trials on kikuyu grass with the aim of adding the tarsonemid kikuyu mite to their labels.

Recommendations flowing from the second objective are:

7. Consideration should be given to funding a post-graduate Ph.D. study to document the life cycle and ecology (including predators) of *Dolichotetranychus australianus* in particular to provide better guidance for control and management programmes. As a stand-alone project, this could be done very cost effectively by funding the operational budget and topping up an existing student scholarship stipend. An alternative would be to apply for an ARC (Australian Research Council) grant for a wider study on grass mites, incorporating this recommendation.
8. Future pesticide strategies, both for mites and for insects, need to be based on chemicals that are ‘softer’ on predators if we are to maximise the degree of natural control of mites and other pests. However, it is clearly not possible to determine the effects on predators of miticides or insecticides used in turf until the identity of those predators has been determined as per recommendation 7.

Scientific Refereed Publications

Knihinicki, D.K., Seeman, O.D., McMaugh, P.E., Loch, D.S., 2017. Phytophagous mite species affecting *Cynodon* spp. (bermudagrasses) and *Pennisetum clandestinum* Hochst. ex Chiov. (kikuyugrass) in Australia. *Crop Science* (submitted).

McMaugh, P., Knihinicki, D.K., Seeman, O.D., Loch, D.S., 2016. Preliminary assessment of mite infestations on warm-season turfgrasses in Australia. *Acta Horticulturae* (in press).

Seeman, O.D., Loch, D.S., McMaugh, P.E., 2016a. Redescription of *Dolichotetranychus australianus* (Trombidiformes: Tenuipalpidae), a pest of bermudagrass *Cynodon dactylon* (Poaceae). *International Journal of Acarology* **42,** 193-205.

Seeman, O.D., Loch, D.S., Knihinicki, D., and McMaugh, P.E. 2016b. A new species of *Steneotarsonemus* (Acari: Tarsonemidae) from Kikuyu Grass, *Pennisetum clandestinum* (Poaceae), in Australia. *Systematic and Applied Acarology* **21,** 889-906.

Intellectual Property/Commercialisation

No commercial IP has been generated.

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Appendices

Appendix 1:

McMaugh, P., Knihinicki, D.K., Seeman, O.D., Loch, D.S., 2016. Preliminary assessment of mite infestations on warm-season turfgrasses in Australia. *Acta Horticulturae* (in press).

Appendix 2:

Seeman, O.D., Loch, D.S., McMaugh, P.E., 2016. Redescription of *Dolichotetranychus australianus* (Trombidiformes: Tenuipalpidae), a pest of bermudagrass *Cynodon dactylon* (Poaceae). *International Journal of Acarology* **42,** 193-205.

Appendix 3:

Seeman, O.D., Loch, D.S., Knihinicki, D., McMaugh, P.E., 2016. A new species of *Steneotarsonemus* (Acari: Tarsonemidae) from Kikuyu Grass, *Pennisetum clandestinum* (Poaceae), in Australia. *Systematic and Applied Acarology* **21,** 889-906.

Appendix 4:

Knihinicki, D.K., Seeman, O.D., McMaugh, P.E., Loch, D.S., 2017. Phytophagous mite species affecting *Cynodon* spp. (bermudagrasses) and *Pennisetum clandestinum* Hochst. ex Chiov. (kikuyugrass) in Australia. *Crop Science* (submitted).

Appendix 5:

Loch, D. 2015. Couch mite…which mite? *Australian Turfgrass Management* **17**(3), 56-59.

Appendix 6:

Loch, D. 2015-16. Couch mite…which mite. *The Telegrass (Sports Turf Association QLD)* **17**, 19-23.

Appendix 7:

Loch, D.S., Seeman, O.D. 2017. Incidence and distribution of mite species across a collection of *Cynodon* spp. (bermudagrass) genotypes growing in subtropical Australia. *International Turfgrass Society Research Journal* **13** (in preparation).

Appendix 8:

Akamine, H., Seeman, O.D., Loch, D.S. 2017. *Dolichotetranychus zoysiae* Ehara, a pest of zoysiagrass turf in Okinawa Island (Japan). *International Turfgrass Society Research Journal* **13** (in preparation).

Preliminary Assessment of Mite Infestations on Warm-Season Turfgrasses in Australia

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Abstract

Phytophagous mites were first identified as a problem in warm-season turfgrasses in Australia around 80 years ago. In production turfgrass fields, slower growth and weakening of sod strength by mites can cause serious commercial losses through breakage of harvested rolls. Elsewhere, mite infestation is associated with poor wear resistance coupled with very slow recovery of turf on playing fields, thereby reducing the usage that is possible on such fields. At the same time, knowledge about turfgrass mites is lacking: specifically, which mite group/species is/are causing damage and to which turfgrass species. There has long been an underlying assumption, based mainly on overseas literature, that mites of the family Eriophyidae are the main cause of the distorted growth symptoms frequently seen and attributed to mite damage. During the 2010/11 growing season, an Australia-wide survey was conducted, sampling seven warm-season turfgrass genera to determine the mites present in each case. This paper reports the results of that survey, together with data from more recent mite infestations sampled during the subsequent three-year period. Based on their frequency of occurrence, tenuipalpid mites from the genus *Dolichotetranychus* appear to be at least as important as eriophyoid mites on *Cynodon* spp.; *Dolichotetranychus* mites were also recorded from two survey samples of *Zoysia* spp. but not in subsequent sampling. Eriophyoid mites of the genus *Aceria* were found on *Cynodon* spp., with possibly a second species on *Zoysia* species. A number of mixed tenuipalpid/eriophyoid populations have also been found on *Cynodon* species. A *Steneotarsonemus* species (Tarsonemidae) was found associated with *Pennisetum clandestinum*. Grass-webbing tetranychid mites (*Oligonychus* spp.) also occasionally affect a wide range of warm-season turf and other grasses non-selectively.

INTRODUCTION

Mites were first identified as a problem in warm-season turfgrasses 80 years ago (Newman, 1934). However, the only mite discussed in the recent turf literature in

Australia or taught in educational courses has been the so-called ‘couch mite’, which has almost universally been assumed to be *Aceria cynodoniensis* (Acari: Eriophyoidea: Eriophyidae), the same species reported to damage *Cynodon* spp. (bermudagrasses/green couch grasses) in the USA (e.g. Keifer, 1960; Keifer et al., 1982).

Because eriophyoid mites are extremely small and almost colourless, they are very difficult to see during dissection of plant material. As a result, the presence of mites is usually determined indirectly based on the distorted rosette-like damage symptoms they cause in affected bermudagrass plants: leaf sheaths on individual shoots become swollen with stunted leaf blades, closely packed, and thickened; and bunches of such shoots proliferate at the affected stem node. The overall distorted rosette is commonly described as a ‘witch’s broom’.

These distorted growths lead to slower grass growth through poor lateral stolon extension and a subsequent lack of turf strength through reduced matting of stolons and poor root development. This is particularly devastating to production turf at harvest, because it results in the cut rolls of sod breaking up or tearing on the harvest conveyer and, hence, loss of product which anecdotally can reach 30% or more. Where mite infestations are lighter allowing intact rolls to be harvested, this simply transfers the problem to the buyer of that turf. Managers of established turf facilities (sports fields, parks, golf courses, bowls greens, race tracks, etc) face two major issues in the event of a mite outbreak at their facility: firstly, reduced use due to poorer wear resistance allied with the extremely slow recovery from wear of the mite-affected turf; and, secondly, the poor quality and uneven nature of the turf surface through distortion and thinning caused by mites.

While the presence of mites and the consequences of such infestations are reasonably well known amongst informed turf agronomists, producers and managers, it was clear that no one really knew exactly which mite species and how many different mite species are present on different turfgrasses. For example, in her book ‘What Garden Pest or Disease Is That?’, Judy McMaugh (1986) listed ‘couchgrass mite’ as the flat-mite *Dolichotetranychus australianus* (Acari: Tetranychoidea: Tenuipalpidae). Also, the generic description of mite damage as ‘witches brooms’ clearly does not fit every case of growth distortion seen in the field, and probable symptoms of mite damage are also apparent on *Pennisetum clandestinum* Hochst. ex Chiov. (kikuyugrass), *Stenotaphrum secundatum* (Walter) Kuntze (St Augustinegrass in USA, buffalograss in Australia) and *Zoysia* spp. (zoysiagrasses). The latter variously include ‘pinetree-like’ growths, shoot proliferation, and looping of stolons into aerial positions without attachment to the soil.

Without knowing exactly which mites are attacking each of the important turfgrasses, effective control measures cannot be devised. Through the results of our survey (2010/11) and additional sampling through to 2014/15, which are presented in this preliminary paper, we have taken the first definitive steps towards unravelling what is clearly a complex area with major implications for the Australian turf industry.

MATERIALS AND METHODS

In the course of our initial one-year survey during the 2010/11 growing season, 112 samples were examined for the presence of mites in the laboratory at Orange, New South Wales (NSW). Sampling was conducted in all Australian states and territories (with the exception of Tasmania and the Northern Territory) and covered seven different groups of perennial warm-season turfgrasses:

Cynodon spp. (green couch/bermudagrass)	41 samples
Pennisetum clandestinum (kikuyugrass)	27
Stenotaphrum secundatum (buffalograss/St Augustinegrass)	15
Zoysia spp. (zoysiagrass)	20
Digitaria didactyla (blue couch)	3
Paspalum vaginatum (seashore paspalum)	4
Sporobolus virginicus (marine couch)	2

Because mites tend to be spread unevenly over an area with “hot spots” showing where the infestation is concentrated, samples were taken where and when the symptoms of mite damage were seen, rather than trying to collect at random across a particular site. Wherever possible, GPS coordinates (later checked against Google Earth using the physical address) were recorded for each collection site, as well as taking photographs of the damage observed. Field samples were wrapped in damp paper, placed in zip-sealed plastic bags, and refrigerated prior to forwarding by Express Post to the laboratory. Overall, samples were taken from turf production farms (41.1%) and other country sites (4.5%), urban open space (including parks, roadsides, lawns and waste land) (30.3%), and sports (11.6%) and research facilities (12.5%).

On arrival in the laboratory, plant samples were placed separately into screw-capped plastic containers with 70% ethanol and shaken for approximately 2 min to extract mites hidden in the foliage; usually, the plant material was partially macerated beforehand to assist in the release of mites. Samples were then vacuum-filtered. For this process to be effective, it was essential to limit the soil contamination in the collected samples to prevent mites from being obscured during examination. Filtered samples were then examined under a stereomicroscope and mites identified to family and genus level. Representative mite specimens were then picked off and mounted on microscope slides for further detailed examination under a compound microscope. Some fresh samples were also dissected directly under a stereomicroscope (50X magnification) for examination, which facilitated photographs of the mites and their eggs.

Subsequent to our initial survey, a further 202 turfgrass samples have been examined, mostly in specialist acarology laboratories in South Brisbane, Queensland (QLD) and Orange (NSW). These came from 110 different Site x Turfgrass Species combinations, with the remainder representing replication across a site (including different varieties of the same turfgrass species) and repeat sampling at the same site over time. Extraction methodology was similar to that described above, though greater use has also been made of direct examination through dissection of fresh samples under a stereomicroscope.

RESULTS

Methodology

Phytophagous mites were extracted from 31.5% of the 112 samples in our initial 2010/11 survey. However, a number of samples arrived at the laboratory in poor condition (12.5%) or had enough soil contamination to make separation of mites very difficult (10.7%). Only 3 of these 26 poor quality samples yielded phytophagous mites, and in one of those the identification was inconclusive. With the notable exception of buffalograss in which all 15 submitted samples were negative, phytophagous mites were recovered from 39.0% of bermudagrass, 33.3% of kikuyugrass, 35.0% of zoysiagrass, and 33.3% of other grass samples. With improved sampling and handling together with greater experience in recognising the external symptoms of mite infestations, phytophagous mites were recovered from 80% of the 202 samples examined during the 4 years following our initial survey.

Bermudagrass/Green Couch

For *Cynodon dactylon* (L.) Pers. and *C. dactylon* x *C. transvaalensis* Burtt Davy collectively, the number of survey samples with phytophagous mites was almost evenly divided between *Aceria* (Eriophyidae) and *Dolichotetranychus* (Tenuipalpidae) species (Plates 1 and 2, respectively) with a single record of an *Abacarus* (Eriophyidae) species from Perth, Western Australia (WA). A similar trend (possibly weighted slightly in favour of *Dolichotetranychus* in terms of frequency) has continued in our subsequent sampling, with the addition of mixed tenuipalpid-eriophyoid populations found in 16 cases.

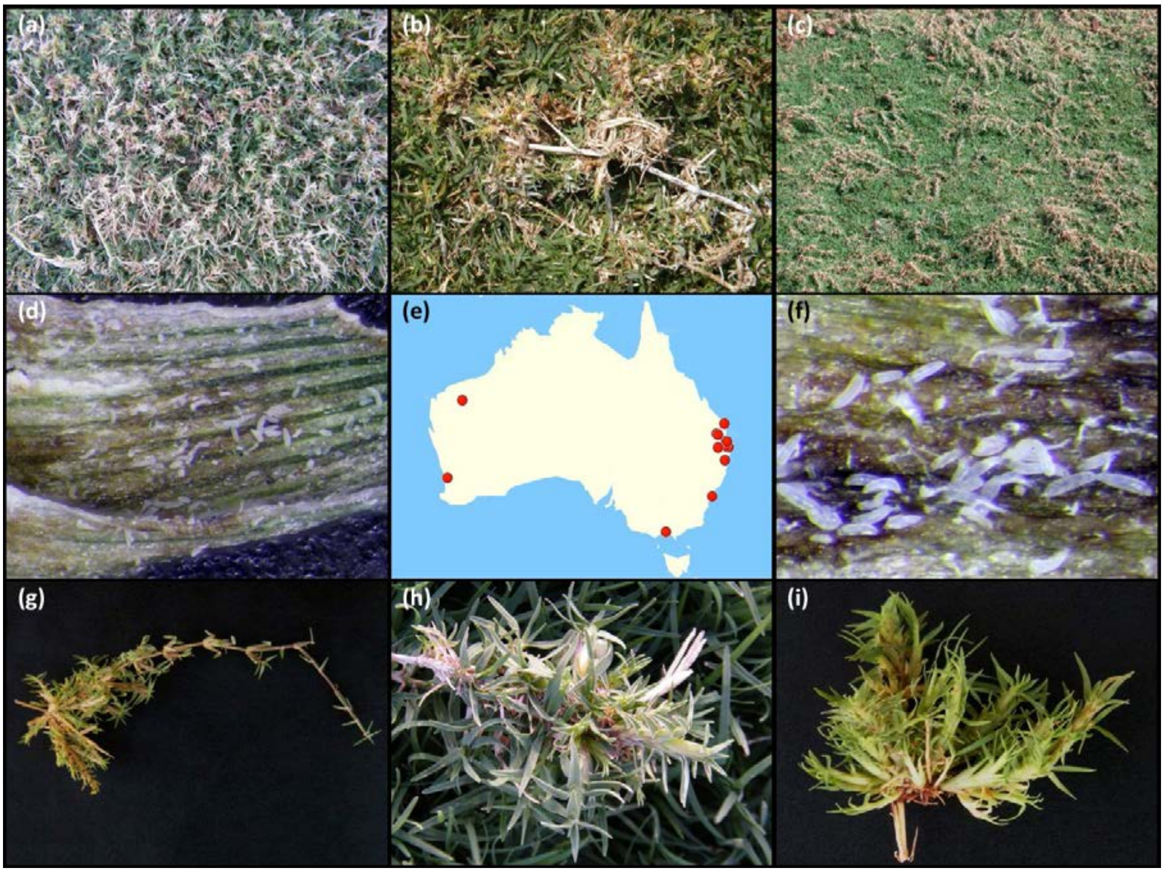

Plate 1. *Aceria* sp. found on bermudagrass: (a) and (b), infested swards showing 'witches brooming' (rosetting) of distorted growths; (c), 'porpoising' of stolons (poorly rooted); (d) and (f), mites and eggs on leaf sheath; (e), Australia-wide distribution based on samples examined; and (g), (h), (i), close-up views of witches brooms and distorted shoots.

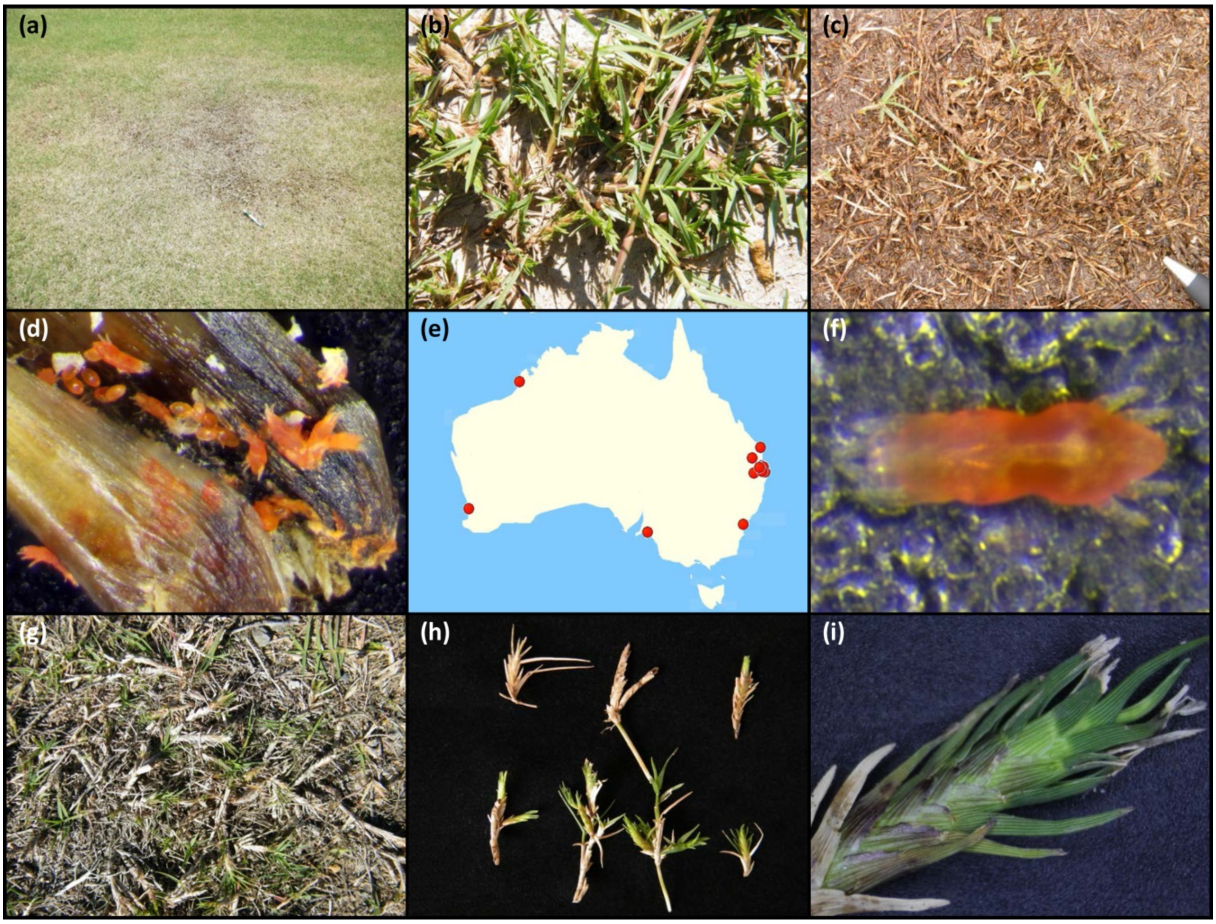

Plate 2. *Dolichotetranychus* sp. found on bermudagrass: (a), weak sward growth typical of *Dolichotetranychus* infestation; (b), sward showing 'pinetree-like' growths without rosetting; (c), death of sward due to severe mite infestation; (d), mites and eggs found under a leaf sheath; (e), Australia-wide distribution based on samples examined; (f), *Dolichotetranychus* sp. mite; (g), old infestation showing elongated pinetree like growths; and (h) and (i), close-up views of pinetree like growths.

The visual symptoms (i.e. the distorted growths, or galls) caused by infestations of these two mites are subtly different. Witch's brooms (rosetted growths at stolon nodes – see also Keifer et al., 1982) and poor stolon root development are typical of *Aceria* infestations, which tend to be concentrated more along the edges rather than being spread across an area. At the same time, individual growths within an *Aceria* witch's broom become shortened with leaves greatly reduced in length, thickened and flattened laterally to give a 'pinetree' effect. The *Dolichotetranychus* species, on the other hand, produces a characteristic thinning and weakening of the stand, usually concentrated in patches, but frequently spread across an infested area rather than being prevalent along the margins. There is markedly less proliferation of distorted growths at stolon nodes (i.e. no strong witch's brooming), and these pinetree-like growths are slightly more thickened and rounded with even shorter leaves than for *Aceria*. *Dolichotetranychus* can also be found persisting in some quite old, half-dead, elongated pinetree-like growths, though not as prevalent as in younger growths. In the case of mixed *Aceria*-*Dolichotetranychus* populations, the external symptoms seen tend to follow the dominant species.

Kikuyugrass

Mites from *Pennisetum clandestinum* appear to be a *Steneotarsonemus* species (Tarsonemidae) from the subgenus *Steneotarsonemoides*. Members of this genus are regarded as phytophagous. Superficially, *Steneotarsonemus* and *Dolichotetranychus* mites can appear similar in size and shape while scanning extracted material under the stereomicroscope, particularly if the characteristic reddish colour of *Dolichotetranychus* mites has been lost through storing plant samples in alcohol for some time, thereby causing some apparent misidentifications during our initial survey (McMaugh et al., 2011). We are currently re-sampling old collection sites and extending the range of locations sampled to confirm the identity of mites found on kikuyugrass. At two sites, this process has yielded adult female *Dolichotetranychus* mites from kikuyugrass growing among, or in close proximity to, heavily-infested bermudagrass. However, rather than indicating kikuyugrass as a preferred host, these results are more suggestive of migratory behaviour, with *Dolichotetranychus* females moving to establish new colonies under less crowded conditions. Repeated sampling (seven times between Sept. 2011 and Aug. 2014) of a key site at Murarrie (QLD) where kikuyugrass grows immediately adjacent to *Dolichotetranychus*-infested bermudagrass has yielded only the tarsonemid mite. Perhaps significantly also, the numbers of tarsonemid mites seen through dissection or recovered by filtration have been appreciably fewer than for tenuipalpid mites infesting bermudagrass.

The visual damage symptoms observed in kikuyugrass infested with mites can vary, particularly between long-cut or uncut grass and short-cut turf. These include poor root development, shortening of the internodes, and a proliferation of side shoots along the elevated stolon. Individually, heavily infested shoots appeared to be shorter and thicker to give a “clubbed” appearance. Leaves may also become bleached (i.e. whitened) in appearance.

Zoysiagrass

Both *Aceria* (5 samples - *Zoysia japonica* Steud*.*, *Z. matrella* (L.) Merr*.*, *Z. pacifica* (Goudswaard) M. Hotta & Kuroki) and *Dolichotetranychus* species (2 samples - *Z. matrella, Z. pacifica*) were recorded in survey samples of zoysiagrass from northern and southern Queensland. Additional samples of eriophyoid mites have been found on zoysiagrasses during the post-survey period, but no *Dolichotetranychus*. *Steneotarsonemus* mites from the subgenus *Neosteneotarsonemus* have also been recovered from distorted growths of *Z. japonica* (1 sample only) in southern Queensland. However, from the limited number of mite infestations recorded on zoysiagrasses, it is not yet possible to describe the visual symptoms accurately.

Other Grasses

Despite showing distinctive symptoms suggestive of mite infestation (e.g. crab-like stolon growth with poor rooting, shortened internodes and witch’s brooming), no plant-feeding mites were extracted from St Augustinegrass during our initial survey in 2010/11. However, a few other mites such as Stigmaeidae, oribatids and acarids were found in some of those samples. This non-result for plant-feeding mites may perhaps have been a case of not sampling the right material or of having taken samples at the wrong time. Subsequently, *Dolichotetranychus* mites were extracted from St Augustinegrass (on three out of five varieties sampled on the same date at a single site), but the significance of this is yet to be determined as re-sampling of the same site two months later failed to find any mites.

In retrospect, we are inclined to discount the significance of the single record from our survey of *Dolichotetranychus* in blue couch (*Digitaria didactyla* Willd.) growing among bermudagrass in Perth (WA). Subsequent sampling of blue couch growing among, or in contact with, bermudagrass heavily infested with *Dolichotetranychus* mites at three locations has proven negative. Moreover, at one of these sites (Mansfield, QLD), the blue couch was conspicuous for its active, apparently healthy growth amongst near-dead bermudagrass heavily infested by *Dolichotetranychus*. This is consistent with Champ's (1961) statement that the "scarlet" couch grass mites he described were confined to bermudagrass (green couch) and had not been recorded from blue couch.

No potentially-damaging mites were recovered from four survey samples of seashore paspalum (*Paspalum vaginatum* Sw.). However, this was not unexpected given the dearth of previous reports of phytophagous mite activity on this species overseas.

Sporobolus virginicus (L.) Kunth is an Australian native species from coastal habitats, but with a pan-tropical distribution worldwide. It is used to a limited extent as a rehabilitation species in disturbed coastal areas, and also has some potential as a highly salt-tolerant turfgrass. Two survey samples taken immediately adjacent to *Dolichotetranychus*-infested bermudagrass showed no trace of the tenuipalpid mites. Instead, *S. virginicus* had its own distinctive suite of mites including those from the genera *Aceria* and *Acunda* (Eriophyidae) and *Monoceronychus* (Tetranychidae). However, very few specimens were found.

DISCUSSION

Within the animal kingdom, mites (Subclass: Acari) are second only to the insects in terms of species diversity, but just 5% or so of the estimated >1 million mite species have been described to date (Walter, 2006). It is therefore not surprising that there are likely to be undescribed mite species present on turfgrasses in Australia.

Warm-Season Turfgrass Mites in Australia

In Australia, the phytophagous mites recorded on the mainstream warm-season turfgrass species come from four different families, namely Eriophyidae, Tenuipalpidae, Tarsonemidae and Tetranychidae. In the first three of these families, the question still under investigation is which species within the specified mite genera is/are responsible for the damage to the various grasses.

1. Eriophyidae. During the 2010/11 survey, eriophyoid mites of the genus *Aceria* were extracted from bermudagrass samples, and an apparently different *Aceria* species was found on zoysiagrasses. The genus *Aceria* was confused with *Eriophyes* following a proposal by Newkirk and Keifer (1971) to revise the type species designation for the latter, which was then corrected by the International Commission on Zoological Nomenclature (Lindquist, 1996). However, the use of *Eriophyes* instead of *Aceria* has persisted in some American publications in relation to the eriophyoid bermudagrass mite (e.g. Williamson et al., 2013).

In the case of bermudagrass, the most likely species is *Aceria cynodoniensis* (bermudagrass mite, couch mite), which is of major concern on *Cynodon* spp. worldwide. *A. cynodoniensis* was originally described by Sayed (1946) from infestations found in Egypt. While Gibson's (1967) collection from NSW is regarded as the first official record of this species in Australia, there is a much earlier record (Newman, 1934) of a similar witch's brooming effect on bermudagrass in Western Australia caused by an *Eriophyes* (now *Aceria*) species, and further taxonomic investigations are pending in relation to this information. However, two other *Aceria* species with apparently more limited distribution globally have also been reported from *Cynodon* spp. as the host plant: *A. cynodonis* in central and western USA (Keifer et al., 1982) and *A. niloticus* in the Sinai Peninsula (Abou-Awad and Nasr, 1983).

Most eriophyoid mites are highly host-specific; and with the use of more sophisticated methods of molecular analysis, even eriophyoid "species" previously thought to be less host-specific are increasingly being shown to consist of a number of cryptic species, each specific to a particular plant species. Early acarologists (e.g. Butler 1963) believed that the bermudagrass mite (*A. cynodoniensis*) is native to Africa. More recently, suggestions in the American literature (e.g. Reinert, 1982; Williamson et al., 2013) have implied that *A. cynodoniensis* is probably native to Australia. However, without any supporting evidence, this does not fit well with the presumed centre of origin for *C. dactylon* being located in the Middle East and its widespread distribution throughout Africa (Harlan and de Wet, 1969), nor with the fact that most (if not all) *Cynodon* genotypes in Australia are derived from recent imports (Langdon, 1954; Jewell et al., 2012).

The *Aceria* species found on zoysiagrasses in Australia may be an undescribed species. *Aceria zoysiae* (zoysiagrass mite) has not been recorded in Australia; and none of the zoysiagrass samples in our survey showed any evidence of the leaf symptoms of buggy-whipping, chlorosis and rolling of the margins that were reported by Baker et al. (1986) as typical of *A. zoysiae* infestations in the USA.

The finding of an *Abacarus* species (1 specimen only) in a bermudagrass sample collected in Perth (WA) is interesting. This appears to be the same species as found in two earlier bermudagrass samples collected from Sydney (NSW) in December 2009 and from Townsville (QLD) in August 2011. Although not frequently collected (or at least identified), this hitherto unknown and unsuspected eriophyoid species, like the better-known *Aceria* couch mite, would appear to have a wide distribution in Australia. Like most eriophyoid mites, it is likely to be a plant feeder; and the same genus includes at least two significant economic pests, *A. hystrix* (cereal rust mite) and *A. sacchari* (sugarcane rust mite). *A. hystrix* occurs in Australia and has a relatively wide host range on cereals and other grasses, though it may eventually prove to be a complex group consisting of specialised races or cryptic species targeting different hosts (Skoracka and Kuczyński, 2006). Abou-Awad and Nasr (1983) described *Abacarus cynodonis* from bermudagrass in the Sinai Peninsula, and specimens from Australia are being compared with this species.

2. Tenuipalpidae. *D. australianus* was described from an infestation on bermudagrass in southern Queensland by Womersley (1943). *Dolichotetranychus* mites were found on *Cynodon* and *Zoysia* species during our 2010/11 survey, although the two samples from the latter species are no longer available for verification. This line of enquiry therefore remains unresolved unless and until additional specimens can be collected from *Zoysia* species. *D. zoysiae*, described by Ehara (2004) from zoysiagrasses in Japan, remains a possibility, but this species has not previously been recorded in Australia.

Prior to our study, *D. australianus* had not been recorded in Australia outside of Queensland (Smiley and Gerson, 1995), but *Dolichotetranychus* mites have now been shown to occur Australia-wide on bermudagrass, from Mt Isa and Charters Towers (QLD) (historical records) to Broome (WA). Although described from an Australian collection, it appears more likely that *D. australianus* originated elsewhere, perhaps in Africa where widely separated infestations on bermudagrass were recorded much earlier in Egypt (Sayed, 1946 - as *D. floridanus*; Wafa et al., 1968-69), Zimbabwe (Goldsmid, 1962) and South Africa (Meyer, 1979).

3. Tarsonemidae. Tarsonemid mites cover a wide range of feeding behaviour, but those on grasses are probably fungivorous or phytophagous. While some tarsonemid mites appeared not to be damaging to the associated grass plants, *Steneotarsonemus* mites found on kikuyugrass and one zoysiagrass sample are significant as this genus is phytophagous. Only *S. ananas* (pineapples), *S. bancrofti* (sugarcane) and *S. laticeps* (lily bulbs) have previously been recorded in Australia and our specimens may represent undescribed species. In NSW, Allen (1967) reported that two unidentified *Tarsonemus* species had been found on kikuyugrass, and were associated with white flecking of the leaves and bronzing of the leaf sheaths. Overseas, infestations of both *S. kruseae* and *T. scaurus* have been recorded from kikuyugrass in Costa Rica (Ochoa et al., 1991, 1994; Lin and Zhang, 2002).

4. Tetranychidae. Colonies of grass-webbing mites (*Oligonychus araneum*, *O. digitatus*) are occasionally seen on a wide range of warm-season turf and other grasses, and these two species often occur together in the same infestation (Gutierrez and Schicha, 1983). Such colonies are obvious even to a casual observer because of the distinctive protective webbing woven over the top of the mites. We recorded only one grass-webbing mite infestation during our four-year study period, but these can be quite numerous in certain years when suitable conditions occur. The two *Oligonychus* species have only been recorded in Australia, with records of infestations going back almost 80 years (Anon., 1936; Davis, 1968).

Visual Symptoms of Mite Infestations

In commercial practice, the diagnosis of a mite infestation is almost invariably based on the symptoms seen on the plant host. For this reason, we have provided detailed illustrated descriptions of symptoms seen on different turfgrass hosts and their association with the different groups of mites identified. With experience, the subtle differences in symptoms on bermudagrass give a reasonable guide as to which of the two major mite species is likely to be involved (or, at least, which might be the dominant species). However, not every rosetted or distorted growth on a plant will yield mites (as our results show). Direct examination through dissection and/or laboratory extraction is the only reliable way to confirm that mites are present and to determine the identity and/or mix of species in an infestation. Cheap portable microscope systems that attach to a computer through a USB port are now available, making direct examination a more feasible option.

Implications for Chemical Registration

Worldwide, relatively few miticides are registered for turf use (Williamson et al., 2013). A recent search of the Australian Pesticides and Veterinary Medicines Authority's (APVMA's) Public Chemical Registration Information System (PUBCRIS) database showed seven products covering four different active ingredients (all adulticides) registered for mite control in turf – a situation that limits opportunities for rotation of chemical groups to minimise the risk of resistance developing. Moreover, all of these registrations are for control of the eriophyoid "couch mite". However, the effectiveness of different miticides varies according to the group of mites targeted, and the chemicals currently registered for couch mite may not be equally effective on tenuipalpid and tarsonemid mites. Previous trial work leading to registration also appears to have been based on indirect observation of symptoms. In the future, data for registration should be based on direct observation of the mites concerned and should cover all of the major species that infest warm-season turfgrasses in Australia. Our ongoing work is aimed primarily at elucidating the taxonomy of the main mite species involved to facilitate future registration of chemicals that are better targeted for their control, as well as providing a base from which future ecological studies of these species can be developed.

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Redescription of *Dolichotetranychus australianus* (Trombidiformes: Tenuipalpidae), a pest of bermudagrass *Cynodon dactylon* (Poaceae)

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ABSTRACT
The flat mite *Dolichotetranychus australianus* (Womersley, 1943) – a significant pest of *Cynodon* turfgrasses in Australia and Africa – is redescribed on the basis of new Australian material collected from *C. dactylon* (bermudagrass, green couchgrass) and its hybrid *C. dactylon* × *transvaalensis*. All active life stages are described, leg chaetotaxy is provided, anomalous features are noted and the specimens compared with type material. The species is widespread in Queensland and is probably present anywhere that *C. dactylon* is grown in Australia, as indicated from its presence in other states. Photographs of its colonies and damage to turfgrass are presented, and damage symptoms are compared with similar damage caused by *Aceria cynodoniensis* (Trombidiformes: Eriophyidae). *Dolichotetranychus summers* Pritchard and Baker, 1952 known from *C. dactylon* in California, is redescribed from type material and confirmed as a species distinct from *D. australianus*, with both sexes of *D. summersi* lacking genital setae *g2*, coxal seta *2b* and the subcapitular seta *m*. Male *D. summersi* also have two solenidia on tarsi I–II and have an aedeagus approximately one-third the length (65 µm) that of *D. australianus* (ca. 200 µm). The species *Dolichotetranychus riyadhensis* Alatawi and Kamran, 2015 is considered a junior synonym of *D. australianus*, and ontogenetic leg chaetotaxy of *Dolichotetranychus zoysiae* Ehara, 2004 is provided and corrected.

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Introduction

Dolichotetranychus australianus (Womersley, 1943) was first described from *Cynodon dactylon* (Poaceae) (green couchgrass in Australia, bermudagrass in the USA) at Gayndah, an inland subtropical town in Queensland, Australia. However, the mite is unlikely to be native to Australia. Significantly, the presumed centre of origin for *C. dactylon* is located in the Middle East and this and other *Cynodon* species are distributed throughout Africa (Harlan and de Wet 1969), while most (if not all) *Cynodon* genotypes in Australia are derived from recent imports (Langdon 1954; Jewell et al. 2012a, 2012b). In Africa, widely separated infestations of *D. australianus* have been recorded throughout the continent for around 40 years or more (as detailed below), whereas in Australia *D. australianus* was thought to be confined to the state of Queensland (Smiley and Gerson 1995) prior to our recent studies reported in the present paper.

The history of *D. australianus* is complicated by some misidentification. Sayed (1938) reported *Dolichotetranychus floridanus* (Banks, 1900) on pineapple, *Phragmites australis* (Poaceae) and *C. dactylon* in Egypt. *Dolichotetranychus floridanus* is a pest of pineapple (Poli 1991) and is rarely found on other host plants (Baker and Pritchard 1956). In the case of the common reed, *P. australis*, the mite in question may be another species, *Dolichotetranychus babylonicus* Al-Gboory, 1987, that was described from *P. australis* in Iraq. Sayed's (1938) record from *C. dactylon*, however, is possibly the first collection of *D. australianus*, and he again reported this species as *D. floridanus* when later describing the eriophyid *Aceria cynodoniensis* Sayed, 1946, often found in mixed colonies with it on *C. dactylon* (Sayed 1946). This error appears to have been repeated by Mohamed et al. (1982), listing *D. floridanus* on *C. dactylon* in Egypt; again, the correct species is almost certainly *D. australianus*.

Wafa et al. (1968–69) confirmed the association of *D. australianus* on *C. dactylon* in Egypt, with records from six localities. Goldsmid (1962) also reported finding it on *C. dactylon* in Zimbabwe. In South Africa, *D. australianus* was collected from hybrid bermudagrass, *C. dactylon* × *transvaalensis* (as *C. X magennisii*) and from *C. incompletus* (as *C. bradleyi*) (Baker and Pritchard 1956; Meyer 1979). An earlier reference by Hall et al. (1955) to a "Red Mite" (attributed to *Stigmaeus*, as initially was *D. floridanus*) on South African turf also appears to be *D. australianus*, particularly from their descriptions of the symptoms seen and the damage it caused. More widely but still essentially in the same region, *D. australianus* has been found in Israel on *C. dactylon* (Meyer and Gerson 1980) and in Iran from soil samples (Baharloo et al. 2006). Recently, a new species, *Dolichotetranychus riyadhensis* Alatawi and Kamran, 2015 (in Alatawi et al. 2015) was described from *C. dactylon* in Saudi Arabia. For reasons explained below, we consider this species a synonym of *D. australianus*.

Cynodon dactylon is also the host plant of another species, *Dolichotetranychus summersi* Pritchard and Baker, 1952, found in the USA. According to Pritchard and Baker (1952), the species differs in the number of genital setae (usual two pairs in *D. australianus*, one pair in *D. summersi*), the subcapitular setae (absent in *D. summersi*) and number of solenidia on the male tarsus (two in *D. summersi*, one in *D. australianus*).

Cynodon dactylon and *C. dactylon* × *transvaalensis* (hybrid bermudagrass) are major warm-season turfgrasses used worldwide from warm temperate areas through to the tropics in North and South America, Australia, Africa and (to a lesser extent) Asia and Europe (e.g. Hall et al. 1955; Kneebone 1966; Beard 1973; Aldous and Semos 1999; Taliaferro 2003; Baltensperger 2014). The best-documented mite that damages these bermudagrass taxa is the eriophyid *A. cynodoniensis* (e.g. Keifer 1960; Tuttle and Butler 1961), which causes a "witches-broom" (rosetted) response at infested plant nodes (see Figure 1a–c). Similar – yet subtly and recognizably different – damage is caused by *D. australianus* (Figure 1d–f), and it is likely that damage by *D. australianus* has

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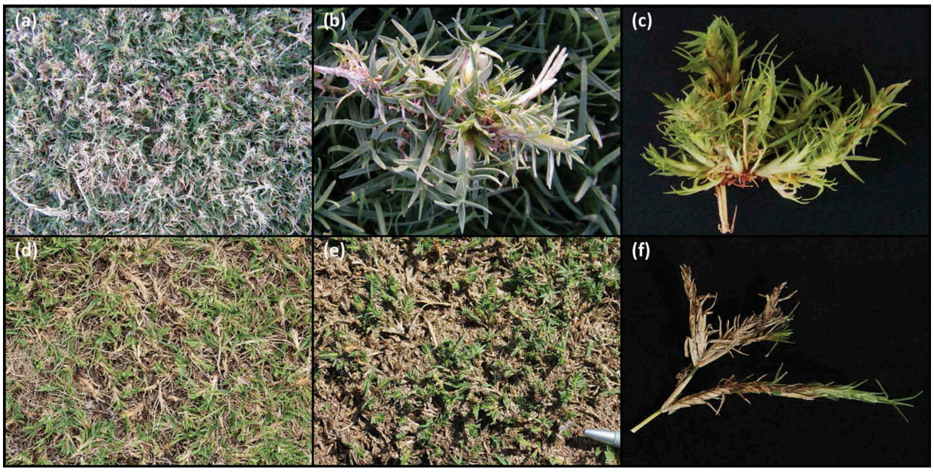


Figure 1. Comparison of visual symptoms of bermudagrass mite infestations on *Cynodon dactylon*: (a), (b) and (c), *Aceria cynodoniensis*; (d), (e) and (f), *Dolichotetranychus australianus*.

often been confused with that of the better known eriophyid mite in the past: for example, the symptoms in the close-up picture used to illustrate Walker's (2014) article about *A. cynodoniensis* were clearly caused by *D. australianus*.

Instead, what little evidence there has been of significant damage caused by *D. australianus* (other than the very early references cited above) has been rare and largely anecdotal. The mite was mentioned as a pest in Egypt (Mohamed et al. 1982). In Australia, Judy McMaugh (1986) listed "couchgrass mite" as *D. australianus*; and Champ's (1961) reference to a scarlet mite causing damage to Queensland bowling greens is also probably that same species. While Smiley and Gerson (1995) indicated that *D. australianus* had not been recorded outside of Queensland, a recent survey of mite damage on Australian turfgrasses finally confirmed the *Dolichotetranychus* mite as a major pest of *Cynodon* turf Australia-wide, roughly equivalent to the eriophyid *A. cynodoniensis* in its frequency of occurrence (McMaugh et al. 2016). To emphasize the importance and the economic implications for the Australian turfgrass industry, a survey of the production turf sector by Haydu et al. (2008) found that *Cynodon* varieties represented almost 40% of the total area of vegetative turf under production.

Accurate taxonomy is essential for decisions on pest control and Australian law requires that chemicals are registered for use on specific pest species. Currently, no miticides are registered for use on *D. australianus*. The overarching aim of this paper is to provide critical taxonomic knowledge of the flat mites attacking *C. dactylon* in Australia. In this context, our objectives are: to describe all active life stages of *D. australianus*; to determine whether *D. australianus* is one species throughout its range in Australia; and to test the validity of *D. summersi*, the other species of *Dolichotetranychus* known from *C. dactylon*. Additionally, we have included field observations on the effects, distribution and host range of *D. australianus*.

Materials and methods

The hypothesis that *D. summersi* and *D. australianus* represent the same species was tested by examining type specimens of *D. summersi* and type specimens, historic collections and fresh material of *D. australianus*. New specimens of *D. australianus* were removed from under sheaths of infested *C. dactylon*, killed in 75% ethanol, mounted in Hoyer's medium, and were examined at a magnification of 1000× using a Nikon Eclipse 80i^{TM} microscope equipped with Nomarski optics and a drawing tube. All measurements are given in micrometres (μm) as ranges. Specimens for measurement were selected after examining all available material and choosing from this a subsample of good-quality specimens from several localities and representing different body sizes. Body size was measured between dorsal setae *v2-h1* for length and between *sc2-sc2* for width (Saito et al. 1999). Distances between setae were measured as the distance from the inside edge of one setal base to the other (i.e. the minimum distance between two setal bases). Leg setal numbers are written as the total number of setae, including eupathidia, followed by the additional number of solenidia in parentheses. Leg setation follows Lindquist (1985), as also presented for *Dolichotetranychus ancistrus* Baker and Pritchard, 1956 in Zhang and Fan (2004). Body setation essentially follows Lindquist (1985). The lateral setae in rows D, E and F are herein considered *d3, e3* and *f3* (following Beard et al. 2012) instead of *d2, e2* and *f2* sensu Zhang and Fan (2004). Although both interpretations may be correct, the former is preferred as the dorsosublateral setae *c2, d2, e2* and *f2* are more often lost in the Tenuipalpidae (Mesa et al. 2009). Coxal setation (notably that of coxa II) follows Zhang and Fan (2004), which is based on positional homology with coxa I, rather than ontogeny. The former is most commonly used in the Tenuipalpidae and we note the ontogeny presented in Seeman and Beard (2011) and Beard et al. (2014) should be corrected: seta *2c* appears in the protonymph, and seta *2b* in the deutonymph. An excellent example of the ontogenetic method is a recent paper by Fuangarworn and Butcher (2015); applied to the Tenuipalpidae, the posterior seta would be *2b* and the anterior seta *2c* (i.e. the reverse).

Abbreviations: QM (Queensland Museum, Brisbane, Australia); SAM (South Australian Museum, Adelaide, Australia); USNM (United States National Museum of Natural History, Beltsville, Maryland, USA); PN protonymph; DN deutonymph.

Results and discussion

Visual symptoms

In *Cynodon* spp., *D. australianus* produces a characteristic thinning and weakening of the stand (Figure 2a–c), usually concentrated in patches, but frequently spread across an infested area rather than being prevalent along the margins as we observed with *A. cynodoniensis* (Loch et al. 2012; McMaugh et al. 2016). In three replicated pot experiments with a *Dolichotetranychus*-infested treatment, reductions in dry matter production of 75%, 70% and 50% were recorded in the mite-infested treatment (D.S. Loch, unpublished data, 2013–2014). However, as noted also by previous authors (Hall et al. 1955; Goldsmid 1962), severe infestations can have an even more devastating effect, causing virtually the whole sward to turn brown and die (Figure 2c).

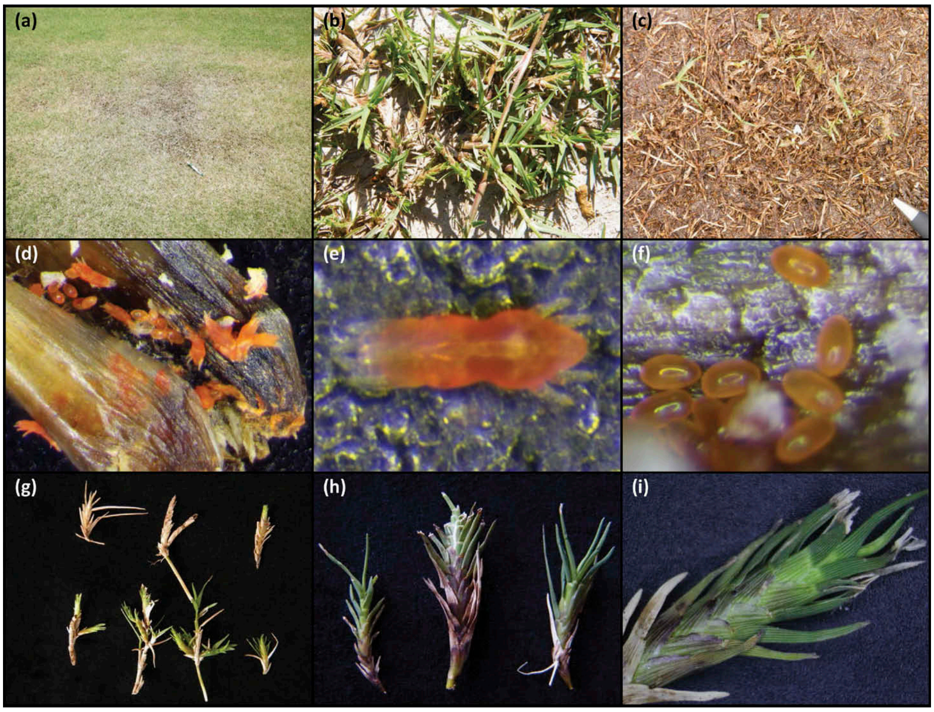


Figure 2. *Dolichotetranychus australianus* mites on *Cynodon dactylon*: (a) weak sward growth typical of *D. australianus* infestations; (b) infested sward showing "pinetree-like" growths without rosetting; (c) death of sward due to severe *D. australianus* infestation; (d) mites and eggs found under a leaf sheath; (e) adult female of *D. australianus*; (f) *D. australianus* eggs; and (g), (h) and (i) close-up views of pinetree-like growths.

There is markedly less proliferation of distorted growths at stolon nodes (i.e. no strong witch's brooming), and these pinetree-like growths are slightly more thickened and rounded with even shorter leaves than for *A. cynodoniensis* (Figure 2g–i – see also Figure 1) due to the activity of the mites living in colonies beneath the leaf sheaths (Figure 2d–f). *Dolichotetranychus australianus* can also be found persisting in some quite old, half-dead, elongated pinetree-like growths, though not as prevalent as in younger growths. In the case of mixed *Aceria–Dolichotetranychus* populations, the external symptoms seen tend to follow the dominant species (pers. obs.).

Damage caused by *D. australianus* is also very similar to that caused by *Dolichotetranychus zoysiae* Ehara, 2004 to *Zoysia matrella* and *Z. tenuifolia* (Poaceae), another important turfgrass (Akamine et al. 2005). So far, *D. zoysiae* has not been detected off Okinawa Island (H. Akamine, personal communication), including 20 samples of *Zoysia* spp. in Australia (McMaugh et al. 2016).

Distribution

The distribution map in Figure 3 shows the Australia-wide occurrence of *D. australianus* based on 23 samples examined here (16 new, 7 historic) plus 52 samples of infested *Cynodon* spp. examined from 2011 to 2015 (Loch et al. 2012; McMaugh et al. 2016). The greater number of occurrences recorded in Queensland reflects the greater intensity of sampling from that state rather than indicating any state-to-state differences per se. However, anecdotal observations by a reliable observer (C. Johnstone, personal communication

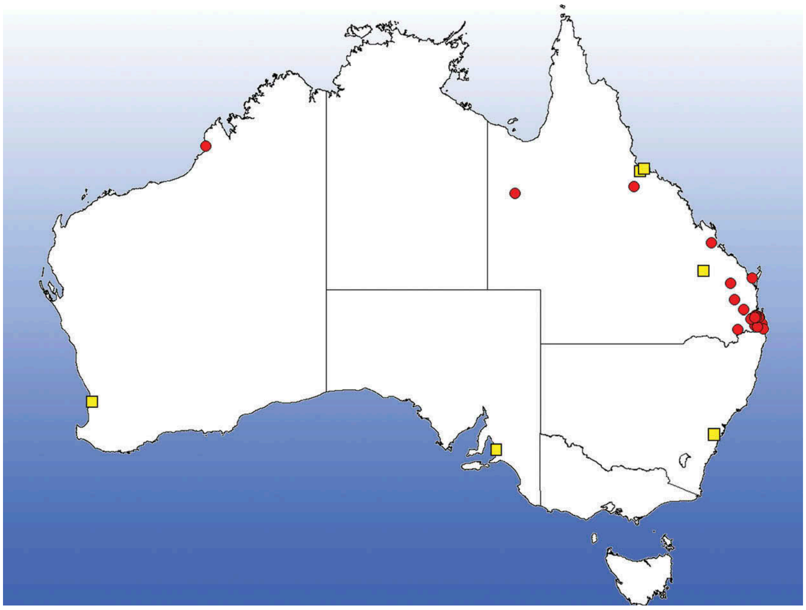


Figure 3. Australia-wide distribution of *Dolichotetranychus australianus* based on specimens examined in this study (circles) and records of *D. australianus* infestations reported by Loch et al. (2012) outside of south-east Queensland (squares).

2015) do suggest a greater incidence of *Dolichotetranychus* rather than *Aceria* mite infestations in tropical north Queensland.

Internationally, *D. australianus* also occurs through Africa (Egypt, Zimbabwe and South Africa) and the Middle East as detailed earlier. Additionally, symptoms on *C. dactylon* consistent with this mite species were recently reported from Bangladesh and the Seychelles in a blog by Woods (2010), suggesting that its distribution may also extend further east into the Indian subcontinent.

Host plants

In our studies, *D. australianus* was consistently found on a range of *C. dactylon* and *C. dactylon* × *transvaalensis* genotypes, but has not been recovered from *C. transvaalensis*. This is consistent with African reports, which also included *C. incompletus* as an additional host plant species (Meyer 1979).

In screening work associated with an initial survey of turfgrass mites in Australia (Loch et al. 2012), we have concluded that there were some apparent misidentifications of *Dolichotetranychus* mites on *Pennisetum clandestinum* (kikuyugrass) that could not be confirmed in later sampling from the same sites (McMaugh et al. 2016). Nevertheless, adult female *D. australianus* mites were recovered from *P. clandestinum* growing among, or in close proximity to, heavily infested *C. dactylon*. However, rather than indicating *P. clandestinum* as a preferred host, these results are more suggestive of migratory behaviour, with *Dolichotetranychus* females moving to establish new colonies under less-crowded conditions.

Similarly, we are inclined to discount the significance of two previous records of *Dolichotetranychus* found on *Digitaria didactyla* (blue couchgrass) growing among *C. dactylon* in Perth (WA) (Loch et al. 2012) and specimens collected in 1986 from Brisbane (QLD). Subsequent sampling of *D. didactyla* growing among, or in contact with, *C. dactylon* heavily infested with *Dolichotetranychus* mites at three locations has proven negative. Moreover, at one of these sites (Mansfield QLD – Figure 2c), *D. didactyla* was conspicuous for its active, apparently healthy growth amongst near-dead *C. dactylon* heavily infested by *D. australianus*. This is consistent with Champ's (1961) statement that the "scarlet" couchgrass mites he described were confined to *C. dactylon* and had not been recorded from *D. didactyla*.

Observations from the Mansfield (QLD) site also provided further clues regarding limitations on the preferred host range of *D. australianus* through the presence of healthy plants of contaminant and weed grass species. From this, it would appear that *Axonopus fissifolius, A. compressus, Digitaria ciliaris, Eleusine indica, Paspalum dilatatum, P. notatum* and *P. urvillei* are not preferred hosts of *D. australianus*.

Dolichotetranychus Sayed, 1938

Type species: *Stigmaeus floridanus* Banks, 1900 – by monotypy.
Stenotetranychus Mitrofanov, 1973: 1317.

Diagnosis

Female body elongated, evenly rounded, without dorsal plates, body striated. Anterior margin of prodorsum without rostral shield, projections or notch. Opisthodorsum with setae *c1–3, d1, d3, e3, f3, h1–2*; setae *e1–2, f2* absent; setae *h2* sometimes long, never flagellate; setae *d3* and *e3* in submarginal position. Anal plates not developed, with one to two pairs of setae (*ps1-2*). Ventral plates not developed, genital plates weakly developed. One or two pairs of genital setae. Palp three segmented. Tibia I–II with four setae. Genua III–IV bare. Tarsal claws uncinate or highly reduced, appearing pad-like in dorsal aspect. Male with posterior opisthosoma elongated, narrowing to a blunt point, modified pseudanal setae *ps1* in membranous tubercle.

Remarks

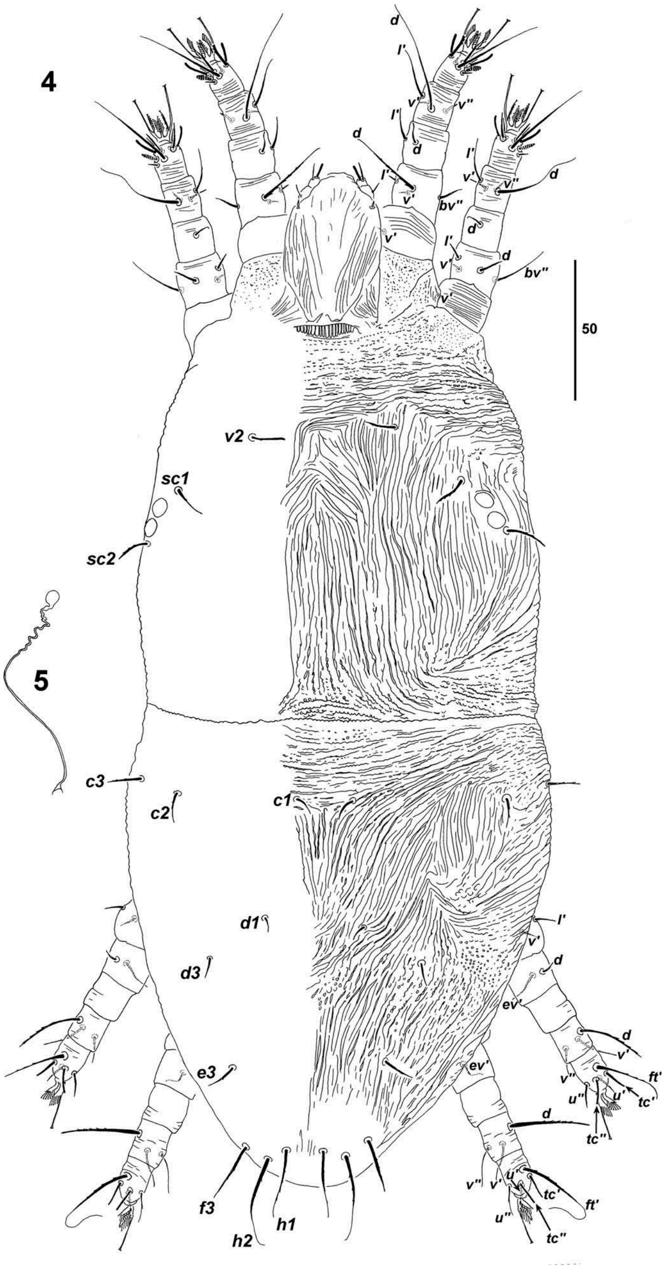
Sayed (1938) claimed that the name *Trichadenus* Rondani, 1870, could not be applied accurately to mites of the genus *Dolichotetranychus* as it is impossible to work out which family of mites was described by Rondani (1870).

Dolichotetranychus australianus (Womersley, 1943)

Trichadenus australianus Womersley, 1943: 246.
Dolichotetranychus riyadhensis Alatawi and Kamran, 2015: 817
syn. nov.
(Figures 4–22)

Diagnosis

Male and female: subcapitular seta *m* present; two pairs of coxa II setae (*2b, 2c* present); two pairs of genital setae; ventral body striae extensively lobed; medial propodosomal striae just posterior to *v2-v2* longitudinal-oblique; trochanters I–IV 1-1-2-0 (*v′* absent on trochanter IV); femora 4-4-2-1 (*l′* present on femora I–II); genua I-II 2-1; tarsi 8(+1)-8(+1)-5-5. Female: genital plate with smooth longitudinal striae; length of dorsal seta on femur I 30–33, extending well past base of dorsal seta on genu II; dorsal seta on femur II short, length



Figures 4–5. *Dolichotetranychus australianus* female. (4) Dorsum, habitus; (5) Spermatheca.

7–9, not extending to base of dorsal seta on genu II; dorsal seta on femur III short, length 6–8. Setal lengths for: *v2* 11–14, *f3* 17–21, *h1* 28–36, *h2* 33–42. Male: aedeagus extremely long, looping within body, length 200–230; one solenidion on tarsi I–II (ω′ absent).

Material examined

Type material. AUSTRALIA: Queensland: 1 male syntype, Gayndah, March 1943, ex couchgrass, det. H. Womersley (J12126); 4 female syntypes, same data as male (J12127, J12128); 17 syntypes (slide spoiled, only five are certainly female; the others are nymphs or females), Gayndah, 9 December 1942, infesting couchgrass on lawn, det. H. Womersley (J12129). All in SAM. Notes: Although Womersley (1943) recorded the type material as collected in "January and February, 1943", the slides (which are clearly marked as syntypes) are from December 1942 and March 1943. The females are in poor condition, but collectively measurements for most structures can be taken. The male specimen is in good condition (although the slide itself is poor), and its measurements are provided in parentheses in the following redescription.

New material examined. AUSTRALIA: QUEENSLAND: 4 females, Redlands, 13 March 2009, A. Manners, ex *C. dactylon*; 20 females, 1 male, 5 DN, 1 PN, 2 larvae, Murarrie, Brisbane, 27°27′44″S 153°06′42″E, 23 September 2011, D. Loch & O. Seeman, ex *C. dactylon*; 4 females, 5 males, 1 DN, 2 larvae, Murarrie, Brisbane, 27°27′32″S 153°07′04″E, 2 November 2011, D. Loch, ex *C. dactylon*. 8 females, 4 males, 1 larva, Redlands Research Station, 27°31′35″S 153°14′45″E, 12 February 2013, D. Loch, ex *C. dactylon* × *transvaalensis*; 2 females, 1 DN, 1 PN, 1 larva, Wecker Rd Rugby League Ground, Mansfield, 27°32′10″S 153°06′40″E, 27 February 2013, D. Loch, ex *C. dactylon*; 6 females, Bay Turf, Hervey Bay, 25°20′40″S 152°50′12″E, 17 May 2013, D. Loch, ex *C. dactylon*; 10 females, 1 male, Pialba Turf, Hervey Bay, 25°21′23″S 152°50′54″E, 17 May 2013, D. Loch, ex *C. dactylon*; 4 females, 3 males, 2 PN, Halcyon Waters, Hope Island, Brisbane, 27°52′49″S 153°21′50″E, Oct 2013, D. Loch, ex *C. dactylon*; 14 females, 5 males, 2 DN, 2 PN, 3 larvae, Mount Petrie School, Mackenzie, 27°32′43″S 153°07′27″E, 12 May 2014, D. Loch, ex *C. dactylon* (Wintergreen); 2 females, 2 males, Albion Tennis Centre, Highlands St, 27°25′44″S 153°02′49″E, 15 March 2013, D. Loch, ex *C. dactylon* × *transvaalensis*; 2 females, corner of Kingaroy & Avoca Streets, Kingaroy, 26°32′42″S 151°50′20″E, 10 December 2014, D. Loch, ex *C. dactylon*; 3 females, 2 males, 1 DN, University of Queensland, St Lucia Campus, 27°29′46″S 153°00′45″E, 14 March 2013, D. Loch, ex *C. dactylon* (TIF Sport); 4 females, Ipswich United Services Bowls Club, East Ipswich, 27°36′29″S 152°46′26″E, 21 January 2015, D. Loch, ex *C. dactylon* × *transvaalensis*; 5 females, Polo field at Tinamba Turf, Beaudesert, 27°58′05″S 152°59′00″E, 19 September 2014, D. Loch, ex *C. dactylon*; 10 females, 5 males, 1 DN, Yeronga, Brisbane, 27°30′37″S 153°00′55″E, O. Seeman, 19 November 2015, ex *C. dactylon*; 9 females, Redlands, 27°31′34″S 153°15′02″E, D. Loch, Nov 2014, ex *Pennisetum clandestinum* among *C. dactylon* infested with *D. australianus*. WESTERN AUSTRALIA: 10 females, 4 DN, 4 PN, 1 larva, Broome, 15 September 2011, L. Halling, ex *C. dactylon*.

Old material examined. (poor slides, all *Dolichotetranychus*, likely *D. australianus*). 9 females, 1 male, 3 DN, 1 PN, plus eriophyids, Toogoolawah, Aug 1936, associated with bunching of couchgrass tips; 8 females, 2 males, Gayndah, 10 December 1942, ex couchgrass*; 3 females, 1 DN, N R'ton [North Rockhampton], 11 January 1954, W.L. Green, ex couchgrass; 7 females, 1 DN, Charters Towers, Jan 1967, ex couchgrass; 6 females, Lake Moondarra, Mt Isa, Nov 1980, I. Cook, ex lawn, suspected of biting man; 3 females, 1 male, Sherwood, Brisbane, 1 December 1986, J.H. Barrett, ex *D. didactyla*. All in QM. * Type collection from same site in early 1943.

Description

Female (10 measured; 153 examined). *Dorsum*. (Figure 4) Body measurements: distance between setae *v2-h1* 255–275; *sc2-sc2* 130–155; other measurements: *v2-v2* 48–56, *sc1-sc1* 100–125, *c1-c1* 16–25, *c2-c2* 130–165, *c3-c3* 150–180, *d1-d1* 30–39, *d3-d3* 75–86, *e3-e3* 46–60, *f3-f3* 36–46, *h1-h1* 8–14, *h2-h2* 22–31. Propodosoma, anterior to setae *v2*, with irregular, transverse striae, becoming broken lobes at a level midway between *v2* and ribbed rostral collar; propodosomal striae posterior to setae *v2* mostly longitudinal; some oblique anteromedially, becoming transverse and lobed posteriorly. Propodosoma and opisthosoma divided by fold of transverse striae. Opisthosoma with longitudinal to oblique striae posterior to setae *c1*, some striae bearing lobes, especially laterad setae *d3*; striae obsolete around setae *f3, h1-2*. Pores absent. Dorsal setae short, slender, smooth or with few minute barbs; setae *f3, h1-2* more conspicuously barbed and slightly longer than other setae. Setal measurements: *v2* 11–14, *sc1* 13–16, *sc2* 16–21, *c1* 7–11, *c2* 9–14, *c3* 10–13, *d1* 6–8, *d3* 8–11, *e3* 7–13, *f3* 17–21, *h1* 28–36, *h2* 33–42.

Venter. (Figure 6) Intercoxal region I-II with smooth longitudinal striae, becoming lobed and transverse posterior to coxa II to setae *3a*; striae between *3a-ag* lobed, longitudinal. Genital setae

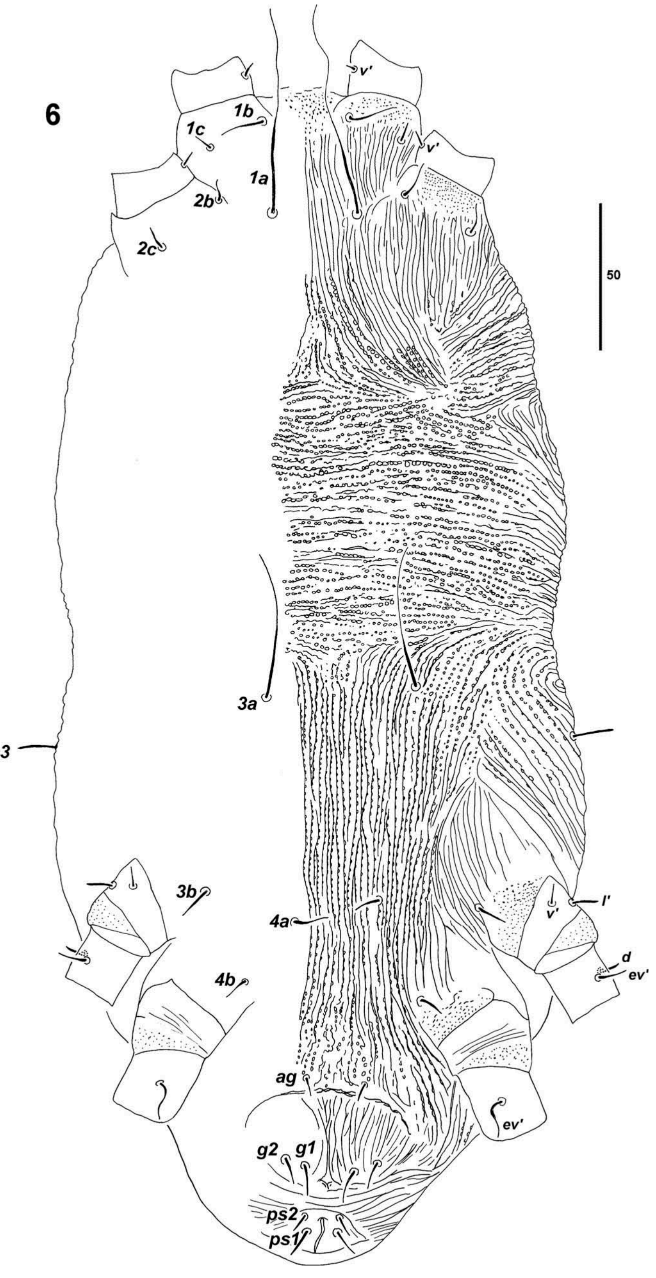
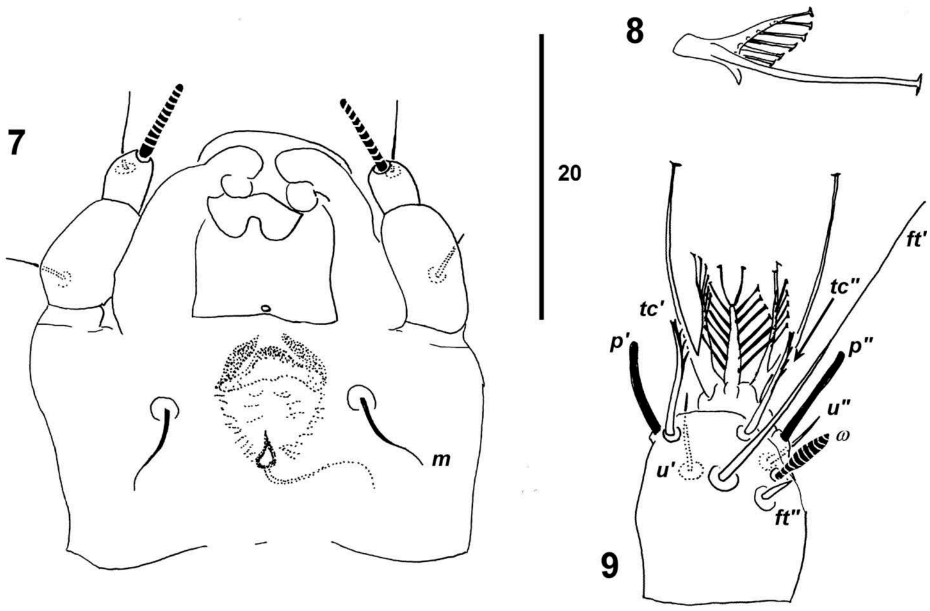


Figure 6. *Dolichotetranychus australianus* female, ventral idiosoma.



Figures 7–9. *Dolichotetranychus australianus* female. (7) Ventral gnathosoma; (8) Empodium, lateral view; (9) Tarsus I, dorsal view.

inserted in more-or-less transverse row, *g1* inserted slightly posterior to level of *g2*. Genital shield weakly defined by smooth longitudinal striae; anal setae *ps1-2* inserted in longitudinal line along inner edge of weakly defined plates. Coxal, genital and anal setae smooth, slender; setae *1a* and *3a* long. Setal measurements: *1a* 60–80, *1b* 14–17, *1c* 6–8, *2b* 7–12, *2c* 7–9, *3a* 50–58, *3b* 6–7, *4a* 12–20, *4b* 5–7, *ag* 4–5, *g1* 9–11, *g2* 8–10, *ps1* 5–6, *ps2* 4–6.

Spermatheca. (Figure 5) Spermatheca a long tube terminating in a distal vesicle 5–6 in diameter.

Palps. (Figures 4, 7) Palps three segmented. Setal formula 0, 1, 1 (+1). Tibiotarsal seta 4–7, solenidion 4–5; tibiotarsal seta inserted just proximal to solenidion.

Legs. (Figures 4, 6, 8–9) Setal formula for legs I-IV (trochanters to tarsi) 1-4-2-4-8(+1), 1-4-1-4-8(+1), 2-2-0-3-5, 0-1-0-3-5, respectively. Tarsi I and II each with one antiaxial solenidion ω" (ta I 5–6, ta II 5–6) and two eupathidia; tectal setae thickened, barbed. Leg chaetotaxy as presented in Figures 4, 6 and 9. Claws small, each bearing one (rarely two) outer long tenent hair and inner ray of six tenent hairs (Figure 9); empodium with seven pairs of tenent hairs (Figure 8). Lengths of selected dorsal setae: *d*FeI 29–33, *d*FeII 7–9, *d*FeIII 6–8, *d*GeI 7–8, *d*TiI 42–48.

Anomalies. Specimen #2 lacks *4b* on both sides; specimen #4 has an asymmetrical expression of two *2b* setae. An unmeasured specimen lacks *h1* on one side.

Male (10 measured; 33 examined). *Dorsum*. (Figure 10) Body measurements: distance between setae *v2-h1* 190–255 (210), *sc2-sc2* 115–130 (135); other measurements: *v2-v2* 42–48 (49), *sc1-sc1* 94–105 (105), *c1-c1* 14–24 (24), *c2-c2* 110–125 (120), *c3-c3* 130–155 (160), *d1-d1* 31–37 (36), *d3-d3* 77–81 (82), *e3-e3* 53–58 (61), *f3-f3* 38–47 (39), *h1-h1* 11–15 (16), *h2-h2* 25–30 (29). Propodosomal striae similar to female, with few lobes. Transverse lobed striae between propodosoma and opisthosoma. Opisthosoma tapering to protruding genital region; opisthosoma with irregular medial striae between setae *c1-d1*, band of transverse striae posterior to setae *d1*, longitudinal striae from level of setae *e3-e3* to setae *h1*. Dorsal setae short, smooth, except setae *f3, h2* slightly thickened, with few barbs; setae *h2* longest of opisthosomal setae. Setal measurements: *v2* 8–12 (9), *sc1* 7–13 (10), *sc2* 9–14 (11), *c1* 6–8 (7), *c2* 7–10 (8), *c3* 7–9 (9), *d1* 5–6 (6), *d3* 5–8 (8), *e3* 6–8 (7), *f3* 9–11 (11), *h1* 10–14 (11), *h2* 12–20 (5).

Venter. (Figure 11) Ventral podosomal striation similar to female. Ventral opisthosoma with transverse lobed striae, becoming irregular and arched just anterior to genital region; dense fold of striae anterior to aggenital setae (delineating where opisthosoma bends upwards sharply in life). Setae *ps1* modified, spine-like, on protruding, terminal turret-like structure; genital setae and setae *ps2* on small membranous tubercules. Coxal setae similar to female. Aggenital and genital setae slender, smooth. Setal measurements: *1a* 48–70 (50), *1b* 6–8 (6), *1c* 4–5 (4), *2b* 5–6 (5), *2c* 4–6 (6), *3a* 37–44 (37), *3b* 5–6 (5), *4a* 6–8 (9), *4b* 5–6 (4), *ag1* 5–10 (5), *g1* 7–10 (10), *g2* 7–11 (10), *ps1* 19–21 (21), *ps2* 11–14 (14).

Aedeagus. (Figure 12) Extremely long, often looping within body, length 200–230 (absent, presumably lost in slide-mounting, in male syntype).

Palps. (Figure 10) Similar to female. Tibiotarsal seta 4–5 (5), solenidion 5–6 (5).

Legs. (Figure 10) Legs similar to female.

Anomalies. Specimen #1 has an asymmetrical loss of seta *e3*.

Deutonymph (5 measured; 18 examined). *Dorsum*. (Figure 13) Body measurements: distance between setae *v2-h1* 210–245, *sc2-sc2* 115–140; other measurements: *v2-v2* 45–53, *sc1-sc1* 92–105, *c1-c1* 16–20, *c2-c2* 115–130, *c3-c3* 140–150, *d1-d1* 26–34, *d3-d3* 66–73, *e3-e3* 40–47, *f3-f3* 34–41, *h1-h1* 6–11, *h2-h2* 20–24. Propodosomal striation similar to female; opisthosoma with transverse striae medially, becoming irregular and sparse posteriorly. Setal measurements: *v2* 10–11, *sc1* 11–13, *sc2* 11–13, *c1* 6–9, *c2* 7–9, *c3* 8–10, *d1* 4–8, *d3* 7–9, *e3* 6–10, *f3* 11–16, *h1* 18–23, *h2* 25–33. Setae *v2, sc1-2, f3, h1-h2* with minute barbs; other dorsal setae smooth.

Venter. (Figure 14) Propodosomal striation similar to female. Opisthosoma with transverse lobed striae. Coxal setae similar to female. Setal measurements: *1a* 40–45, *1b* 8–11, *1c* 5–7, *2b* 2–5, *2c* 4–7, *3a* 20–34, *3b* 5–6, *4a* 7–9, *4b* 2–6, *ag* 4–5, *g1* 4–5, *ps1* 3–5, *ps2* 3–5.

Palps. Similar to female. Tibiotarsal seta 2–4, solenidion 4–5.

Legs. (Figures 14, 17, 20) Setation for legs I-IV differs from adult female by seta *v*′ absent on trochanters III, seta *l*′ absent on femur I-II, seta *d* absent on genu I-II; setal formulae (trochanters to tarsi): 1-3-1-4-8(+1), 1-3-0-4-8(+1), 1-2-0-3-5, 0-1-0-3-5, respectively.

Protonymph (5 measured; 11 examined). *Dorsum*. Body measurements: distance between setae *v2-h1* 160–195, *sc2-sc2* 110–125; other measurements: *v2-v2* 37–46, *sc1-sc1* 81–95, *c1-c1* 14–24, *c2-c2* 105–111, *c3-c3* 120–145, *d1-d1* 21–29, *d3-d3* 52–68,

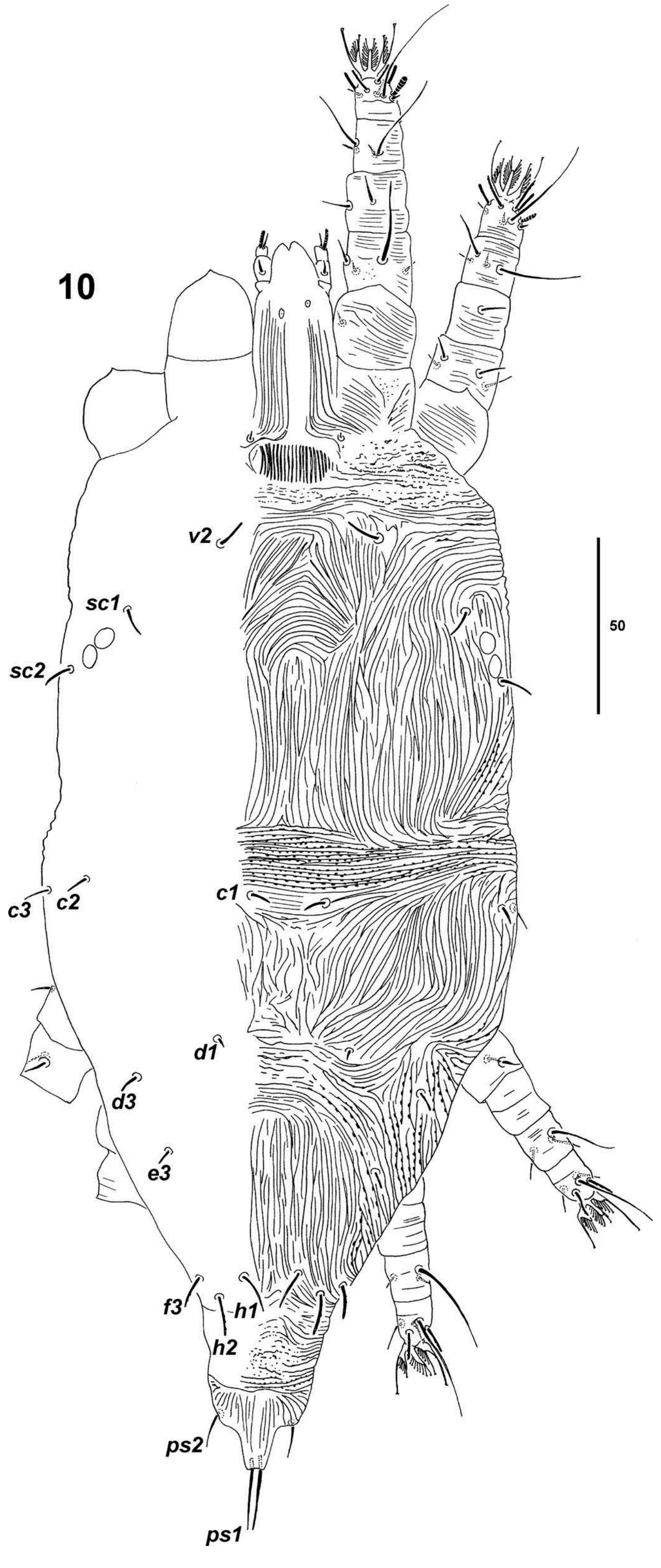


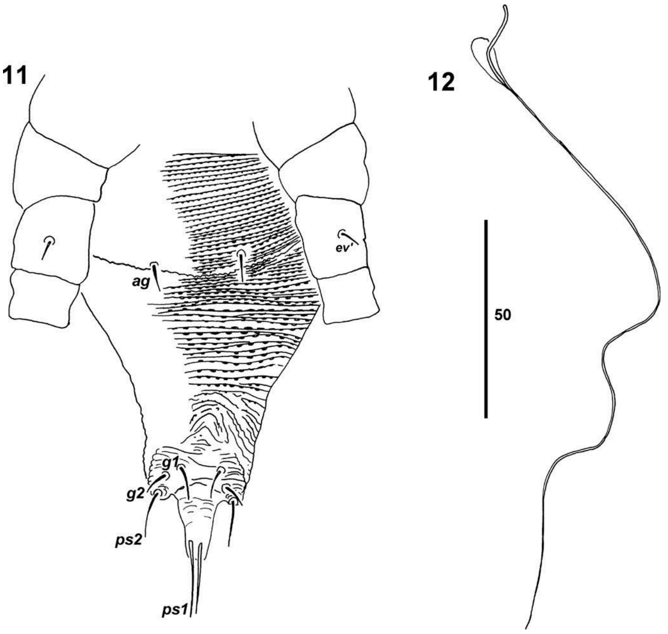
Figure 10. *Dolichotetranychus australianus* male, dorsum, habitus.

e3-e3 34–41, *f3-f3* 27–30, *h1-h1* 6–7, *h2-h2* 38–42. Striation similar to deutonymph. Setal measurements: *v2* 9–12, *sc1* 9–12, *sc2* 9–11, *c1* 7–8, *c2* 7–10, *c3* 7–11, *d1* 5–6, *d3* 6–9, *e3* 6–9, *f3* 9–12, *h1* 13–21, *h2* 18–23. All dorsal setae with minute barbs.

Venter. (Figure 15) Propodosomal striation similar to female. Opisthosoma with broken, transverse striae. Setal measurements: *1a* 35–45, *1b* 7–9, *1c* 2–4, *2c* 2–5, *3a* 18–20, *3b* 3–5, *ag* 2–3, *ps1* 2–3, *ps2* 2–4.

Palps. Similar to female. Tibiotarsal seta 3–4; solenidion 3–4.

Legs. (Figures 15, 18, 21) Setation for legs I–IV differs from deutonymph by setae (*tc*) absent on tarsus IV; setal formulae (trochanter to tarsi): 0-3-1-4-8(+1), 0-3-0-4-8(+1), 1-2-0-3-5, 0-1-0-3-3, respectively.



Figures 11–12. *Dolichotetranychus australianus* male. (11) Ventral opisthosoma; (12) Aedeagus.

Larva (5 measured; 10 examined). *Dorsum*. Body measurements: distance between setae *v2-h1* 110–150, *sc2-sc2* 85–110; other measurements: *v2-v2* 20–32, *sc1-sc1* 72–78, *c1-c1* 15–20, *c2-c2* 85–105, *c3-c3* 95–110, *d1-d1* 20–23, *d3-d3* 50–52, *e3-e3* 31–35, *f3-f3* 23–28, *h1-h1* 4–7, *h2-h2* 9–14. Striation similar to deutonymph. Setal measurements: *v2* 9–14, *sc1* 12–15, *sc2* 11–13, *c1* 8–13, *c2* 9–13, *c3* 12–14, *d1* 5–11, *d3* 10–12, *e3* 7–12, *f3* 9–14, *h1* 9–13, *h2* 13–17. All dorsal setae with small barbs.

Venter. (Figure 16) Propodosomal striation similar to female. Opisthosoma with longitudinal, lobed striae. Setal measurements: *1a* 18–27, *1b* 3–6, *3a* 10–14, *ps1* 2–5, *ps2* 2–3.

Palps. Similar to female. Tibiotarsal seta 2–3; solenidion 3–4.

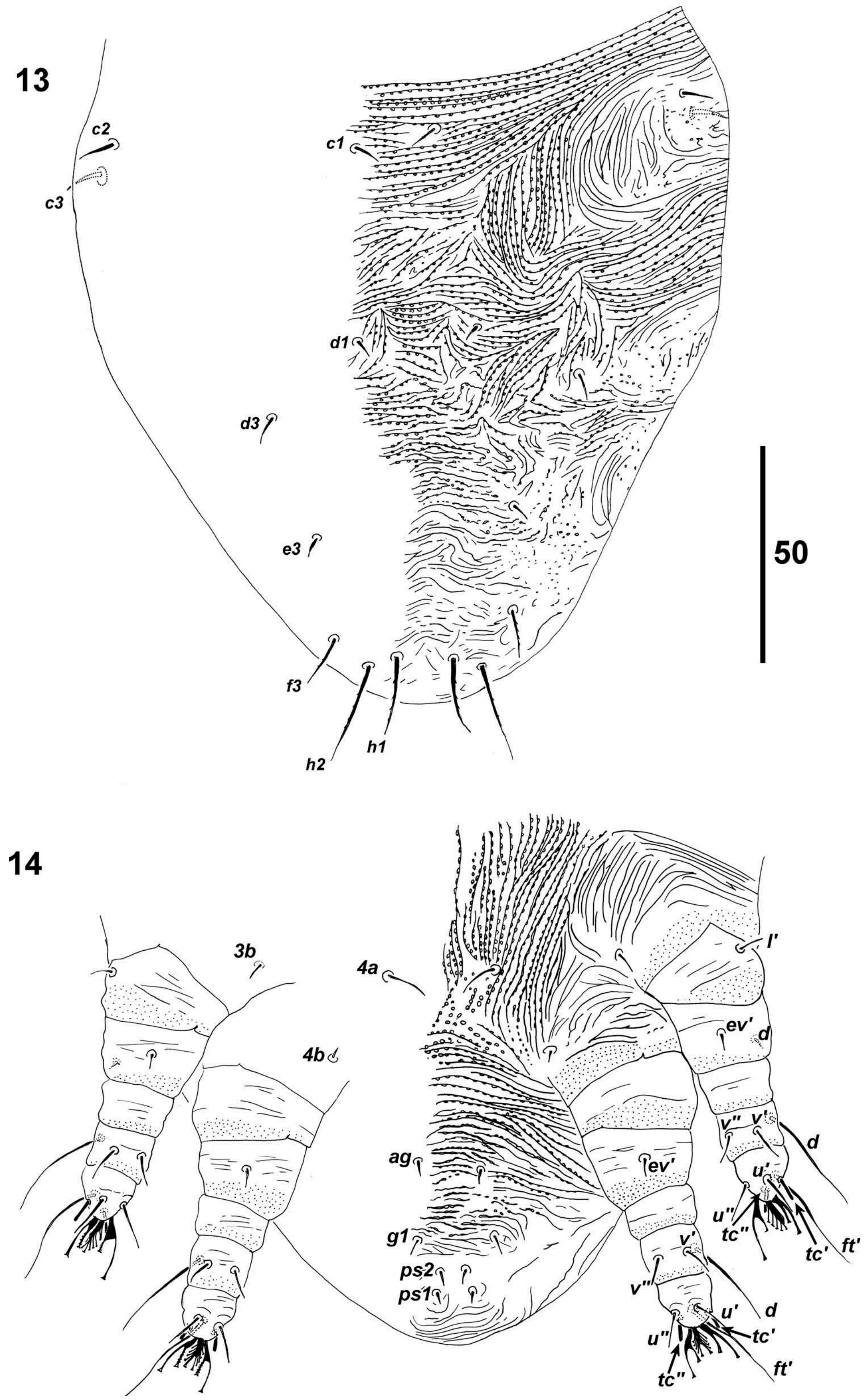
Legs. (Figures 16, 19, 22) Setation for legs I–III differs from protonymph by seta *l′* absent on trochanter III, setae (*tc*) absent on tarsi I–III; setal formulae (trochanters to tarsi): 0-3-1-4-6(+1), 0-3-0-4-6(+1), 0-2-0-3-3, respectively.

Remarks

The specimens from Western Australia did not differ in any feature or measurement from collections from South-east Queensland. Similarly, specimens collected from other host plants (*P. clandestinum, D. didactyla*) were identical to those from *C. dactylon*. As explained previously (see *Host plants*), we do not regard these as true host plants for *D. australianus*. Furthermore, the record from *D. didactyla*, collected in 1986, could be explained by a host misidentification, as blue and green couchgrass can appear similar in a mown sward.

The leg setation and ontogeny of leg setae for *D. australianus* is the same as *D. ancistrus* as reported in Zhang and Fan (2004) and for *D. zoysiae* (personal observation) (Table 1). The leg setation of these three species shows some ontogenetic delays compared to data from Lindquist (1985), Seeman and Beard (2011) and Beard et al. (2014). These setae are: TrIII *v′* in the adult (usually DN), Fe-II *l′* in the adult (usually DN) and Ge I *d* in the adult (usually DN). The description of *D. zoysiae* by Ehara (2004) needs one correction: femur III has two setae (*d, ev′*), as found in most Tenuipalpidae. The diagnostic character states that distinguish the species from *D. australianus* are confirmed, i.e. absence of seta *2b* and subcapitular seta *m*, and the presence of two solenidia on the male's tarsi I-II.

Recently, Alatawi et al. (2015) described *D. riyadhensis* from *C. dactylon* in Saudi Arabia. The species was compared with *D. australianus*, purportedly differing from it by having one



Figures 13–14. *Dolichotetranychus australianus* deutonymph. (13) Dorsal opisthosoma; (14) Ventral opisthosoma.

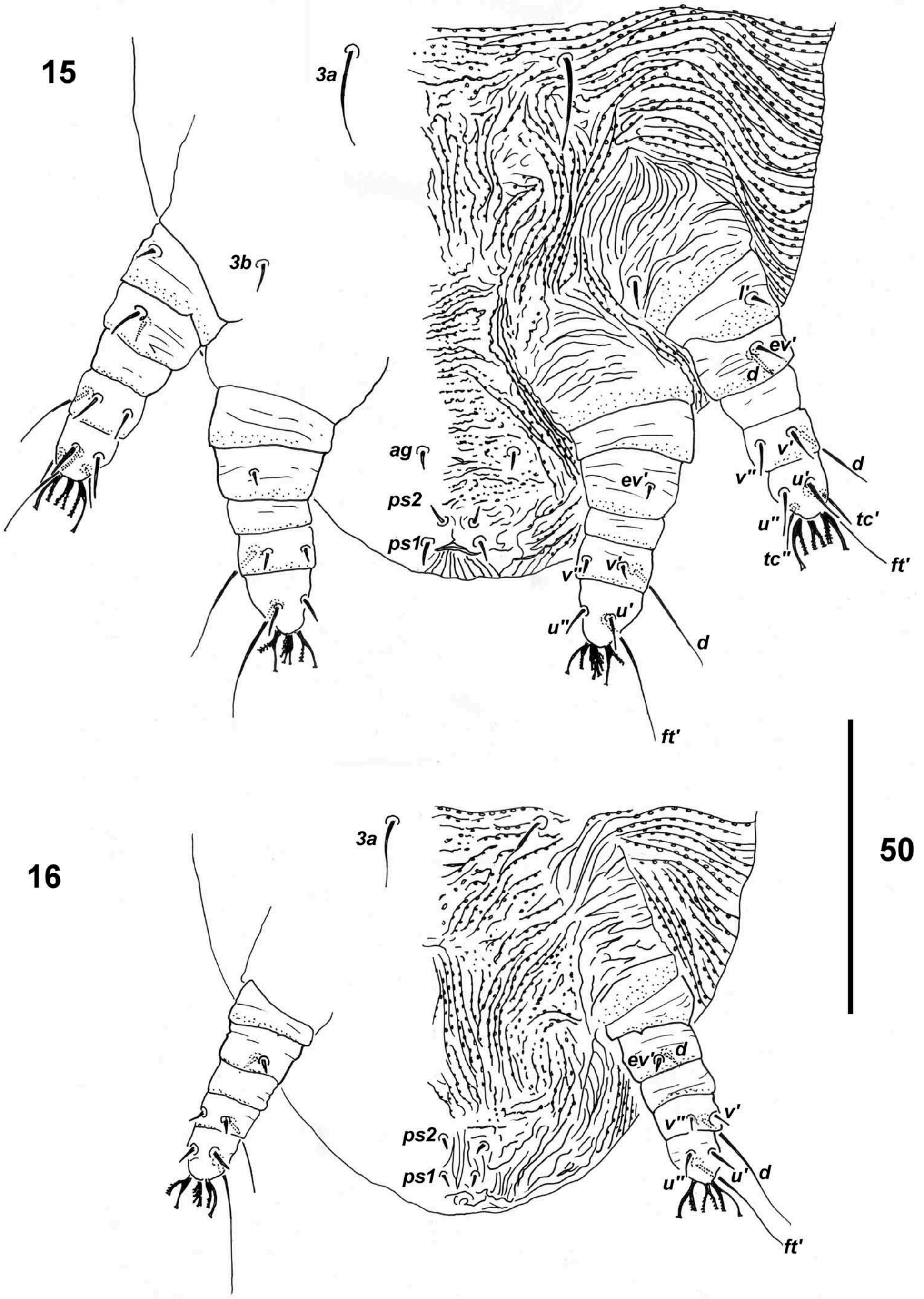
solenidion on the male's tarsus I (versus two in *D. australianus*) and the ratio of the lengths of *1a* as compared to *4a* (5.5–7 versus 4–5 in *D. australianus*) and *v2*/*v2*–*v2* (0.22–0.25 versus 0.4–0.5 in *D. australianus*). However, male *D. australianus* have one solenidion on tarsus I (not two) and the lengths of *1a*, *4a* and *v2*, and the distance *v2*-*v2*, of female *D. australianus* are all within the ranges reported for *D. riyadhensis*. The description of *D. riyadhensis* is of high quality, allowing for detailed comparison, and it is therefore certain that *D. riyadhensis* is a junior synonym of *D. australianus*. Its occurrence in Saudi Arabia is also consistent with prior reports of this species in the Middle East. We emphasise that flat mites are often host-specific to plant genera or species (e.g., Mesa et al. 2009; Beard et al. 2014). Specimens from these host plants should be examined, as descriptions are often lacking in essential detail or have errors.

Dolichotetranychus summersi Pritchard and Baker, 1952

Dolichotetranychus summersi Pritchard and Baker, 1952: 45
(Figures 23–27)

Material examined

UNITED STATES OF AMERICA: CALIFORNIA: Paratypes: 4 females, 1 male, Bond's Corner, 15 mi. E Calexico, Imperial Valley, 26 December 1948, F.M. Summers, ex Bermuda grass. In USNM.



Figures 15–16. *Dolichotetranychus australianus* ventral opisthosoma. (15) Protonymph; (16) Larva.

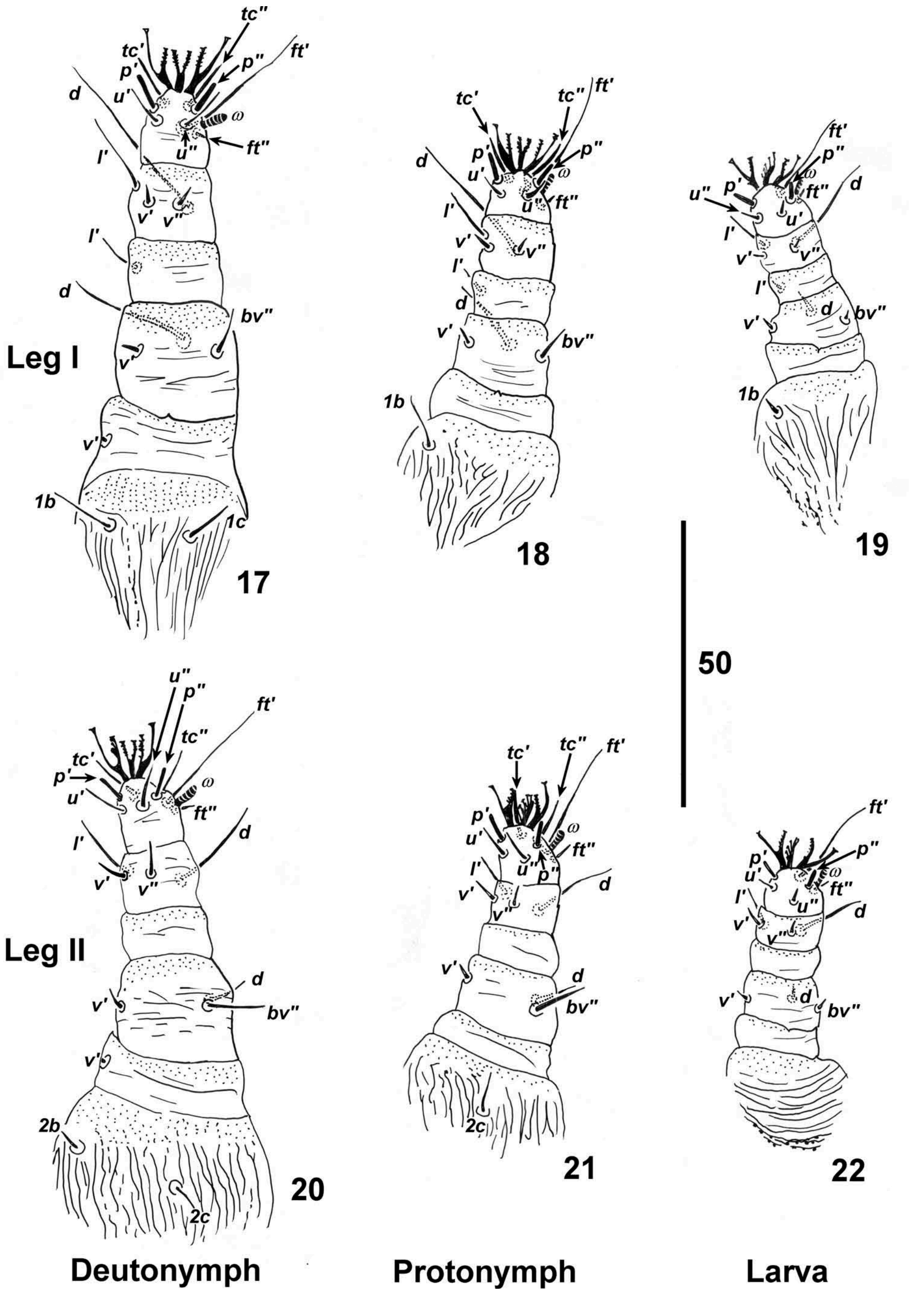
Diagnosis

Male and female: subcapitular seta *m* absent; coxal seta *2b* absent; one pair of genital setae; ventral body striae smooth or weakly lobed; medial propodosomal striae just posterior to *v2-v2* transverse; trochanters I–IV 1-1-2-0 (*v*′ absent on trochanter IV); femora 4-4-2-1 (*l*′ present on femora I–II); genua I–II 2-1. Female: genital plate with smooth longitudinal striae; length of dorsal seta on femur I 30–35, extending well past base of dorsal seta on genu II; dorsal seta on femur II short, length 10–14, not extending to base of dorsal seta on genu II; length of dorsal seta on femur III 14–17. Setal lengths for: *v2* 14–18, *f3* 14–17, *h1* 18–20, *h2* 20–24; tarsi 8(+1)-8(+1)-5-5, male tarsi 8(+2)-8(+2)-5-5. Male: aedeagus short, straight, length 65; tarsi 8(+2)-8(+2)-5-5 (ω′ present).

Description

Female (4 measured). *Dorsum*. (Figure 23) Body measurements: distance between setae *v2-h1* 230–260; *sc2-sc2* 125–155; other measurements: *v2-v2* 46–56, *sc1-sc1* 110–120, *c1-c1* 18–21, *c2-c2* 120–135, *c3-c3* 140–165, *d1-d1* 25–30, *d3-d3* 67–78, *e3-e3* 44–55, *f3-f3* 43–50, *h1-h1* 9–16, *h2-h2* 27–33. Anterior propodosoma with transverse striae that also extend between and just posterior to setae *v2*; propodosomal striae otherwise most longitudinal, becoming transverse posteriorly. Propodosoma and opisthosoma divided by band of transverse striae. Opisthosoma with longitudinal to oblique striae posterior to setae *c1*; striae obsolete around setae *f3, h1-2*. All striae without lobes or weakly lobed. Pores absent. Dorsal setae short, slender, smooth or with few minute barbs; setae *f3, h1-2* more conspicuously barbed and slightly longer than other setae. Setal measurements: *v2* 14–18, *sc1* 18–24, *sc2* 17–22, *c1* 7–10, *c2* 15–20, *c3* 14–21, *d1* 6–7, *d3* 14–17, *e3* 14–17, *f3* 14–17, *h1* 18–20, *h2* 20–24.

Venter. (Figures 24–25) Intercoxal region I-II with smooth longitudinal striae, becoming transverse posterior to setae *1a* to setae *3a*; striae between *3a-ag* longitudinal. All striae smooth. Genital shield weakly defined by smooth longitudinal striae, with one pair of genital setae; anal setae *ps1-2* inserted in longitudinal line along



Figures 17–22. *Dolichotetranychus australianus* legs I–II, ventral view. (17) Leg I, deutonymph; (18) Leg I, protonymph; (19) Leg I, larva; (20) Leg II, deutonymph; (21) Leg II, protonymph; (22); Leg II, larva.

inner edge of weakly defined plates. Coxal, genital and anal setae smooth, slender; setae *1a* and *3a* long. Setal measurements: *1a* 65–80, *1b* 14–19, *1c* 8–10, *2b* absent, *2c* 10–14, *3a* 61–70, *3b* 8–9, *4a* 10–13, *4b* 6–9, *ag* 5–8, *g1* 9–10, *g2* absent, *ps1* 5–9, *ps2* 5–7.

Palps. (Figure 23) Palps three segmented. Setal formula 0, 1, 1 (+1). Tibiotarsal seta 10–11, solenidion 4–5; tibiotarsal seta subterminal, obviously inserted proximal to solenidion.

Spermatheca. Spermatheca a long tube, vesicle not visible in any specimens.

Legs. Setal formula for legs I–IV (trochanters to tarsi) 1-4-2-4-8 (+1), 1-4-1-4-8(+1), 2-2-0-3-5, 0-1-0-3-5, respectively. Tarsi I and II each with one antiaxial solenidion ω″ (ta I 5–6, ta II 5–6) and two eupathidia. Lengths of selected dorsal setae: *d*FeI 30–35, *d*FeII 10–14, *d*FeIII 14–17, *d*GeI 9–12, *d*TiI 45–51.

Anomalies. One specimen expresses *g2* on one side (Figure 25).

Male (1 measured). *Dorsum*. Body measurements: distance between setae *v2-h1* 190, *sc2-sc2* 115; other measurements: *v2-v2* 38, *sc1-sc1* 87, *c1-c1* 19, *c2-c2* 110, *c3-c3* 130, *d1-d1* 25, *d3-d3* 59, *e3-e3* 40, *f3-f3* unmeasurable, *h1-h1* 11, *h2-h2* 26. Propodosomal striae similar to female. Transverse smooth striae between propodosoma and opisthosoma. Opisthosoma tapering to protruding genital region; opisthosoma with irregular medial striae between setae *c1-d1*, band of transverse striae posterior to setae *d1*, longitudinal striae from just posterior to setae *e3-e3* to setae *h1*. Dorsal setae short, smooth, except setae *f3, h1-2* slightly thickened, with few barbs; setae *h2* longest of opisthosomal setae. Setal measurements: *v2* 10, *sc1* 14, *sc2* 17, *c1* 5, *c2* 13, *c3* 16, *d1* 5, *d3* 8, *e3* 8, *f3* 12, *h1* 12, *h2* 15.

Venter. (Figure 27) Ventral podosomal striation similar to female. Ventral opisthosoma with transverse weakly lobed striae, becoming broken just anterior to genital region; dense fold of striae anterior to aggenital setae (delineating where opisthosoma bends upwards sharply in life). Setae *ps1* modified, spine-like, on protruding, terminal turret-like structure 15 long; setae *ps2* slender; one pair of genital setae present (*g2* absent). Coxal setae

Table 1. Ontogenetic development of leg setae in *Dolichotetranychus australianus* Womersley.

	Coxa	Trochanter	Femur	Genu	Tibia	Tarsus
Leg I						
Larva	*1b*	–	*d*, *v'*, *bv"*	*l'*	*d*, (*v*), *l'*	(*u*), (*pζ*), (*ft*), *ω"*
Protonymph	–	–	–	–	–	(*tc*)
Deutonymph	*1c*	*v'*	–	–	–	–
Adult	–	–	*l'*	*d*	–	–
Leg II						
Larva	–	–	*d*, *v'*, *bv"*	–	*d*, (*v*), *l'*	(*u*), (*pζ*), (*ft*), *ω"*
Protonymph	*2c*	–	–	–	–	(*tc*)
Deutonymph	*2b*	*v'*	–	–	–	–
Adult	–	–	*l'*	*d*	–	–
Leg III						
Larva	–	–	*d*, *ev'*	–	*d*, (*v*)	(*u*), *ft'*
Protonymph	*3b*	*l'*	–	–	–	(*tc*)
Deutonymph	–	–	–	–	–	–
Adult	–	*v'*	–	–	–	–
Leg IV						
Protonymph	–	–	*ev'*	–	*d*, (*v*)	(*u*), *ft'*
Deutonymph	*4b*	–	–	–	–	(*tc*)
Adult	–	–	–	–	–	–

Setae are indicated in the stage in which they first appear. Setae in parentheses represent pairs.

similar to female. Aggenital and genital setae slender, smooth. Setal measurements: *1a* 40, *1b* 5, *1c* 5, *2c* 6, *3a* 45, *3b* 5, *4a* 7, *4b* 6, *ag1* 9, *g1* 7, *ps1* 15, *ps2* 9; setae *2b* and *g2* absent

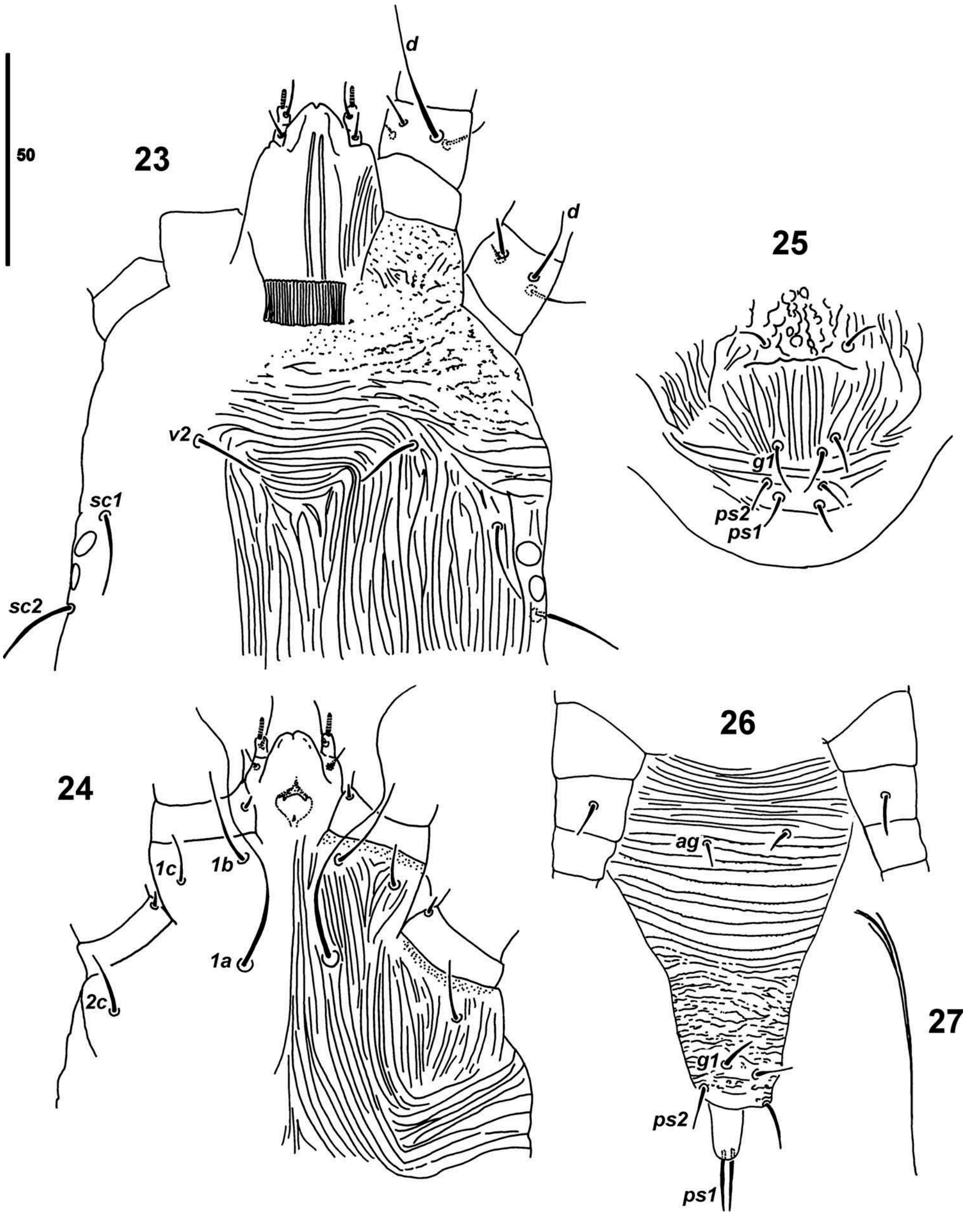
Palps. Similar to female. Tibiotarsal seta 5, solenidion 6.

Aedeagus. (Figure 27) Slender, not looping within body, length 65.

Legs. Legs similar to female, except two solenidia on tarsi I-II (ω′ present).

Remarks

Pritchard and Baker (1952) reported that *D. summersi* had one pair of genital setae (lacking *g2*), lacked the subcapitular setae *m* and that males had two solenidia on tarsi I–II. These characters are different from *D. australianus* (*g1-2, m* present; male without *ω*′) and are confirmed here. This study also found that *D. summersi* lacks the anterior coxal seta *2b* and male *D. summersi* has a much smaller aedeagus (65 µm) than *D. australianus* (ca. 200 µm). Furthermore, *D. summersi* has smooth or weakly lobate striae, but those of *D. australianus* are heavily lobed. This feature is not altered by the age of the specimens as the lobed striae of *D. australianus* are obvious in the specimens collected in 1936 and mounted sometime prior to 1942. More subtle differences are



Figures 23–27. *Dolichotetranychus summersi*. (23) Female, dorsal propodosoma; (24) Female, ventral propodosoma; (25) Female, genitoanal region, specimen with asymmetric seta *g2*; (26) Male, ventral opisthosoma; (27) Male, aedeagus.

found in striation patterns, such as the strial pattern between and posterior to *v2-v2* (Figures 4, 23), in setal lengths [e.g., female *D. summersi* have longer setae *d3* (14–17 versus 8–11) and *d* on femur III (14–17 versus 6–8)], and distances between setae (e.g., male *D. summersi* have *d3-d3* 59 versus 77–81).

Therefore, the hypothesis that *D. summersi* could be a misidentification of *D. australianus* is rejected. *Dolichotetranychus summersi* is a valid species, known from *C. dactylon*, the same host as *D. australianus*. This raises the question as to whether or not *C. dactylon* is a true host plant for *D. summersi*, even though it has been collected three times from *C. dactylon* and no other host (Pritchard and Baker 1952; Baker and Pritchard 1956).

False host records are possible when infested host plants grow in proximity to other plants, such as our records of female *D. australianus* on *P. clandestinum* growing in mixed swards of heavily infested *C. dactylon*. Immature stages for *D. summersi* are unknown, but unfortunately the absence of immatures in the works and collections of Pritchard and Baker (1952) and Baker and Pritchard (1956) could be a result of them discarding immature stages, as no immature stages are described for any of their species. Pending recollection of *D. summersi*, we think it best to consider *D. summersi* a potential pest species of *C. dactylon*, and therefore of biosecurity concern to Australia. Likewise, *D. australianus* is of similar concern to regions of the world, such as the USA, without this mite species and where *Cynodon* is an important commercial turfgrass.

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A new species of *Steneotarsonemus* (Acari: Tarsonemidae) from kikuyu grass, *Pennisetum clandestinum* (Poaceae), in Australia

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Abstract

A new species of tarsonemid mite, *Steneotarsonemus hippodromus* **sp. nov.**, is described from kikuyu grass *Pennisetum clandestinum* (Poaceae). The new species is the fifth species of the subgenus *Steneotarsonemoides*. Keys to the subgenera of *Steneotarsonemus* and species of *Steneotarsonemoides* are provided, as is a list of species in each subgenus of *Steneotarsonemus.*

Keywords: taxonomy, key, catalogue, turf grass

Introduction

Steneotarsonemus Beer (Acari: Tarsonemidae) is a diverse genus of tarsonemid mites comprising 78 species found almost exclusively on monocotyledonous plants (Lin & Zhang 2002; Lofego & Gondim Jr 2006; Lin *et al.* 2009; Table 1). True grasses (Poaceae) are the typical hosts, but several species inhabit sedges (Cyperaceae), and others live on bamboos, bromeliads, coconut, lilies and orchids (Lin & Zhang 2002; Lofego & Gondim Jr 2006). Records from non-monocotyledonous plants are rare (e.g., Cromroy 1958; Livshits *et al.* 1979; Lin & Zhang 2005). Some *Steneotarsonemus* are pests: e.g., *Steneotarsonemus ananas* Tryon on pineapple (e.g., Petty *et al.* 2002); *Steneotarsonemus laticeps* (Halbert) on lily bulbs (e.g., Lynch 1993); and *Steneotarsonemus spinki* Smiley on rice (e.g., Gutierrez 1967; Karmakar 2008). The last species is implicated in virus disease transmission (Shikata *et al.* 1984).

Steneotarsonemus species are widespread in the northern hemisphere, particularly in the temperate zone, but also occur in the frigid zone (Lindquist 1986). The genus is either severely understudied or depauperate in the southern hemisphere. Apart from *Steneotarsonemus* found on plants of economic importance throughout the world, such as the pest species mentioned above, the only other species from the southern hemisphere are *Steneotarsonemus concavuscutum* Lofego & Gondim Jr, which is regarded as a pest of coconut in Brazil (Lofego & Gondim Jr 2006), *Steneotarsonemus brasiliensis* Flechtmann from sugarcane in Brazil (Smiley *et al.* 1993), and *Steneotarsonemus ramus* Lin & Zhang and *Steneotarsonemus mayae* Lin & Zhang from native plants in New Zealand (Lin & Zhang 2005). *Steneotarsonemus madecassus* Gutierrez, described as a pest of rice in Madagascar, is most probably another example (Gutierrez 1967). Although considered as a synonym of *S. spinki* by Tseng & Lo (1980) [and listed as such in Lin & Zhang (2002)], comparison of types by Gutierrez (in Chow *et al.* 1980) and Smiley *et al.* (1993) provide evidence the two species are different, and the species are considered separately here.

Steneotarsonemus are elongate-bodied mites that tend to feed on grasses. Lindquist (1986) defined the genus in detail, and characterised the genus by their relatively broad subcircular gnathosoma, with tiny palps adpressed, in addition to several synapomorphies that bind *Steneotarsonemus* and its likely sister genus *Ogmotarsonemus* Lindquist (Lindquist 1986). Six subgenera of *Steneotarsonemus* are recognised: *Carextarsonemus* (11 spp.), *Mahunkacarus* (5 spp.), *Neosteneotarsonemus* (6 spp.), *Parasteneotarsonemus* (1 sp.), *Steneotarsonemoides* (4 spp.) and *Steneotarsonemus* (53 spp.) (Lindquist 1986; Mitrofanov & Sharonov 1988).

Species of *Steneotarsonemus* show a repetitious diversity in their morphology. Yet there is remarkable diversification, sometimes on the same host-plant. Five species live on rice *Oryza sativa* —plus another four on other *Oryza* spp. Another eight species occur on *Carex* spp. These unspecific host plant identifications prevent proper analysis of host specificity in *Steneotarsonemus*, but those on rice, plus the three found on common reed, *Phragmites communis*, show that multiple species do utilise the same host plant. On the other hand, host-specificity may not be widespread in the genus, with 22 species found on more than one host plant (Lin & Zhang 2002). The identification or biological significance of several records are doubtful, such as *S. spinki* on grape, but collectively these species with multiple host records show that host-specificity cannot be assumed in *Steneotarsonemus*.

Herein, a new species of *Steneotarsonemus* is described from kikuyu grass, *Pennisetum clandestinum*, in Australia. Kikuyu grass is a forest margin species native to the highlands (c. 1500–3000 masl) of tropical eastern and central Africa (e.g. Stapf 1921; Edwards 1935; Mears 1970; Bogdan 1977; Wipff 2003; Clayton *et al.* 2006 onwards), and is now widely grown throughout the world in the lowland subtropics and temperate zones as well as tropical highlands. Although initially developed as a forage/pasture grass, it is also extensively used as a turfgrass, both domestically as a lawn grass, and in industries such as horse racing. In some situations and in some countries (e.g. parts of USA), it is considered a weed. Previously, one species of *Steneotarsonemus* has been recorded from kikuyu grass, *Steneotarsonemus kruseae* Ochoa *et al.* from Costa Rica (Ochoa *et al.* 1991). This species is not host specific, being also collected from a bamboo, *Chusquea* sp., and deertongue *Panicum clandestinum*. Only three species of *Steneotarsonemus* have previously been recorded from Australia: *S. ananas* and *S. laticeps*, both mentioned above as pest species; and the sugarcane stalk mite, *Steneotarsonemus bancrofti* (Michael) (Tryon 1898; Rainbow 1906; Williams 2000).

Material and Methods

Tarsonemid mites were collected from kikuyu grass by stripping leaf blades and sheaths, and shaking them for one minute in 50 mL of 75% ethanol, which was drained through a sieve into a petri dish, allowed to settle, and examined. Some mites were also removed directly from grass, with the aid of a stereomicroscope, where they formed small colonies close to the node, often just under the sheath. Specimens were cleared in Nesbitt's fluid, slide-mounted in Hoyer's medium and examined with a Nikon Eclipse 80i microscope equipped with DIC and a drawing tube. Specimens for scanning electron microscopy were dehydrated with Hexamethyldisilazane, sputter-coated with gold, and examined in a Hitachi TM-1000 Tabletop microscope.

Morphological terminology follows Lindquist (1986), except the ventral subcapitular seta is labelled *su* (such as in Podapolipidae; e.g., Seeman & Nahrung 2013). All measurements are micrometres and are lengths unless otherwise specified; the measurement of the holotype is followed by the range in parentheses. Specimens for measurement were selected after examining all available material and choosing from this a subsample of good-quality specimens from several localities and representing different body sizes.

Results

Steneotarsonemus Beer, 1954

Type species: *Steneotarsonemus hyaleos* Beer, 1954, by original designation.

Diagnosis. As of Lindquist (1986).

Remarks. Lin & Zhang (2002) provided a catalogue of species for *Steneotarsonemus*, including data on their distribution and host plants. However, they did not resolve which species of *Steneotarsonemus* belonged in the subgenera of Mitrofanov & Sharonov (1988); this is provided in Table 1. We caution that the placement of species into subgenera is based on literature, not examination of specimens, and future refinement is necessary. This is especially true for the subgenus *Steneotarsonemus*, particularly those species with rudimentary descriptions. For example, Lindquist (1986) expected that the species *Steneotarsonemus martorelli* Cromroy was a member of *Phytonemus* Lindquist (Lindquist 1986).

One species was overlooked in Lin & Zhang (2002), *Steneotarsonemus sayedi* Zaher & Kandeel collected from soil under bamboo in Egypt (Zaher 1986), and four species have been described since 2002 (Lin & Zhang 2005; Lofego & Gondim Jr 2006; Lin *et al.* 2009). A further species, *Steneotarsonemus zaheri* Omar from sesame and beetroot in Egypt (Omar 2011) is treated here as a Tarsonemidae, *incertae sedis*. This species is certainly not a *Steneotarsonemus* and the female is very likely to be *Polyphagotarsonemus latus* (Banks). The male does share some aspects of *P. latus*, such as the morphology of leg IV, but because it is so unusual it cannot be assigned to a genus.

Subgenus *Steneotarsonemoides* Mitrofanov & Sharonov, 1988

Type species: *Steneotarsonemus panshini* Wainstein & Beglarov, 1968, by original designation.

Differential diagnosis. The subgenus *Steneotarsonemoides* is most succinctly diagnosed as members of *Steneotarsonemus* with a prodorsal lobe extending part-way over the gnathosoma. In their diagnosis for the subgenus, Mitrofanov & Sharonov (1988) also noted that the trichobothrium was always present (separating it from the subgenus *Mahunkacarus*), the presence of a tracheal atrium, small sejugal apodemes, and variable development of the poststernal apodeme. Four species were included in the subgenus and this new species is the fifth (Table 1).

Remarks. Lindquist (1986) provided a full diagnosis and description for the genus *Steneotarsonemus* and four subgenera: *Mahunkacarus*, *Neosteneotarsonemus*, *Parasteneotarsonemus* and *Steneotarsonemus*. Working independently of Lindquist (1986), Mitrofanov & Sharonov (1988) also classified *Steneotarsonemus* into subgenera. They recognised and briefly diagnosed *Carextarsonemus*, *Mahunkacarus*, *Steneotarsonemoides* and *Steneotarsonemus.* Each system of classification recognised small subgenera of uncertain relationship to the larger morass of *Steneotarsonemus (Steneotarsonemus)* species.

Despite working independently, the subgeneric classifications of Lindquist (1986) and Mitrofanov & Sharonov (1988) are complementary. Both recognised the subgenus *Steneotarsonemus* and the previously proposed subgenus *Mahunkacarus*, which comprised four species according to Mitrofanov & Sharonov (1988). Lindquist's (1986) other two subgenera, *Parasteneotarsonemus* and *Neosteneotarsonemus*, comprised just one and three species, respectively, and it is probable that none of these species were considered or examined by Mitrofanov & Sharonov (1988). This left the majority of species treated by Lindquist (1986) in the subgenus *Steneotarsonemus*.

TABLE 1. Subgenera of *Steneotarsonemus* and their species, updated from Lin & Zhang (2002). For full references and information on hosts and distribution, refer to Lin & Zhang (2002). The *incertae sedis* species *Steneotarsonemus zaheri* Omar is not included.

Carextarsonemus
    casteli Livshits *et al*., 1982
    crassisetis Livshits *et al*., 1979
    erlangensis Schaarschmidt, 1959
    intermedius Livshits *et al*., 1982
    livschitzi Sharonov, 1983
    paradoxus Magowski, 1985
    silvaticus Livshits *et al*., 1982
    sininflatus Livshits *et al*., 1979.
    typhae Oudemans, 1929
    vagans Livshits *et al*., 1979
    variabilis Livshits *et al*., 1982
Mahunkacarus
    abruptus Livshits *et al*., 1982
    apertimerus Mahunka, 1971
    badulini Wainstein, 1979
    gibber Suski, 1970
    mayae Lin & Zhang, 2005
Neosteneotarsonemus
    arcticus Lindquist, 1986
    guangzensis Lin *et al*., 1995
    kerguelenensis Fain, 1976
    mirabilis Tseng & Lo, 1980
    ramus Lin & Zhang, 2005
    trisetus Lin & Zhang, 1995
Parasteneotarsonemus
    phyllophorus Ewing, 1924.
Steneotarsonemoides
    azureus Mitrofanov & Sharonov, 1988
    cerinus Mitrofanov & Sharonov, 1988
    panshini Wainstein & Beglarov, 1968
    porrectus Livshits *et al*., 1981
    hippodromus Seeman *et al*. **sp. nov.**
Steneotarsonemus
    acricorn Lin & Zhang, 1995
    acuticlavus Wainstein,1979.
    agropyri Wainstein, 1979
    ananas Tryon, 1898
    arcuatus Livshits *et al*., 1979
    aristidae Mohanasundaram, 1984
    bancrofti Michael, 1890
    brasiliensis Flechtmann, 1993
    canestrinii Massalongo, 1897
    caucasicus Sharonov, 1988
Steneotarsonemus (continued...)
    chiaoi Tseng & Lo, 1980
    comosus Ochoa *et al*., 1991
    concavuscutum Lofego & Gondim Jr 2006
    corruptus Livshits *et al*., 1981
    culmicolus Reuter, 1900
    dzemilae Khydyrov, 1998
    friedmani Smiley, 1967
    furcatus De Leon, 1956
    graminis Kramer, 1886
    hamakuaensis Goff, 1986
    hatzinikolisi Emmanouel, 1981
    hordei Emmanouel & Smiley, 1985
    hyaleos Beer, 1954
    insolitus Livshits *et al*., 1981
    keiferi Beer, 1958
    konoi Smiley & Emmanouel, 1980
    krameri Kuhn, 1883
    kruseae Ochoa *et al*., 1991
    laticeps Halbert, 1923
    latipes Ewing, 1939
    longicorpus Lin & Zhang, 1997
    madecassus Gutierrez, 1967
    martorelli Cromroy, 1958
    medianus Livshits *et al*., 1981
    oconnori Delfinado, 1976
    oryzae Targioni-Tozzetti, 1878
    panici Mohanasundaram, 1984
    paspali De Leon, 1956
    perezi Cromroy, 1958
    phragmitidis Schlechtendal, 1898
    pulchellus Tseng & Lo, 1980
    rectus Livshits *et al*., 1979
    rivalis Tseng & Lo, 1980
    saccharum Lin *et al*., 2009
    sayedi Zaher, 1986
    spinki Smiley, 1967
    spirifex Marchal, 1902
    stipa Lin & Liu, 1999
    subfurcatus Lin & Zhang, 1990
    trihonidae Emmanouel, 1984
    varicosus Livshits *et al*., 1981
    vasiljevae Sharonov, 1983
    zhejiangensis Yu *et al*., 1983

The classification system of Mitrofanov & Sharonov (1988) recognised two other subgenera within the genus *Steneotarsonemus*, *Carextarsonemus* and *Steneotarsonemoides*. *Carextarsonemus* was defined by its anterior process near the medial extremity of apodeme 3 (also present in *S. (M.) abruptus* Livshits *et al.* 1982) and *Steneotarsonemoides* was defined by having a prodorsal lobe. Species in both subgenera would be considered part of the subgenus *Steneotarsonemus* by Lindquist (1986), thus these subgenera are further subdivisions of *Steneotarsonemus (Steneotarsonemus)* sensu Lindquist (1986). Therefore, all subgenera in both classifications are recognised here.

The following key is provided to help identify subgenera. It is over-simplified, as the works of Mitrofanov & Sharonov (1988), and most work on this genus (e.g., Livshits *et al*. 1982), paid little attention to characters of the legs, and their diagnoses and descriptions are comparatively brief compared to those of Lindquist (1986). Thus, some features, particularly leg setation, are unknown for many species, making it difficult to assess the importance of leg setal characters within the genus.

Key to the subgenera of *Steneotarsonemus*

This key combines those presented in Lindquist (1986) and Mitrofanov and Sharonov (1988). This key is provisional and *Steneotarsonemus* is in need of a thorough revision.

1. **Female adult**: prodorsal bothridia reduced, their setae vestigial… . . . . *Mahunkacarus*
– **Female adult**: prodorsal bothridia well developed, their setae capitate or narrowly lanceolate but not reduced in size… 2
2. **Female adult**: prodorsal bothridia slender or narrowly lanceolate. **Larva and adult:** where known, tarsi II and III with unguinal seta *u″* modified, either split to its base or expanded or hyaline . . . . … *Neosteneotarsonemus*
– **Female adult**: prodorsal bothridia capitate. **Larva and adult:** where known, tarsi II and III with seta *u″* unmodified (slender, smooth) or vestigial …. 3
3. **Female adult**: Prodorsum with tectum-like flange extending over mid-dorsal part of gnathosoma…. . . . . *Steneotarsonemoides*
– **Female adult**: Prodorsum without flange extending over gnathosoma…. 4
4. **Female adult**: Apodemes 3 with anterior projection near the medial extremity, in addition to their oblique proximal portion…. . . . . *Carextarsonemus*
– Apodemes 3 without anterior projection, restricted to typical oblique proximal portion (which, distally, may curve posteromedially), or further reduced to remnant… 5
5. **Male adult**: Prodorsum with 3 pairs of setae; leg IV with anterolateral flange as well as large posterolateral flange on femorogenu, with small flange on tibia, and with reduced knob-like tarsal claw. **Larva and adult**: where known, femur II with 2 setae. **Female adult**: where known, legs I and II short and stubby, tarsus II no longer than its basal width; legs III no longer than legs IV (trochanters and ambulacra excluded) . . . . *Parasteneotarsonemus*
– **Male adult**: Prodorsum with 4 pairs of setae; leg IV with or without large posterolateral flange on femorogenu, usually lacking supplementary flanges on this or other segments, and with normal, unguiform tarsal claw. **Larva and adult**: where known, femur II with 3 setae. **Female adult**: where known, legs I and II moderately short but not stubby, tarsus II usually longer than its basal width; legs III longer than legs IV (trochanters and ambulacra excluded) IV… . . . . *Steneotarsonemus*

Steneotarsonemus (Steneotarsonemoides) hippodromus sp. nov.

Diagnosis. All life stages: femur II with two setae; tarsus II stubby, only slightly longer than wide. Adult female: Seta *v1* positioned at anterolateral corner of prodorsal shield, anterior of stigmata; bothridial seta *sc1* capitate, its head broadly lanceolate; seta *c2* positioned far anterior of seta *c1*; pore *ia* positioned far anterior of seta *d*; setae *c1–2, d, f* slender, smooth, setae *e, h, ps* slender, with minute barbs; sejugal apodeme reduced to lateral remnant, length 6–10, oriented obliquely at approximately 45°; apodemes 3 not reaching level of seta *3a*; apodeme 4 reduced to minute element near seta *3b*; seta *2b* positioned posterior to apodeme 2; seta *3a* not reaching trochanter III; leg IV short, not extending beyond idiosomal margin; seta G *v′* IV not reaching base of seta Ti *v′* IV. Adult male: Prodorsum with four pairs of setae; seta *sc1* about twice as long as seta *sc2*; seta *c2* not reaching base of *c1*; seta *c1* not reaching base of seta *d*; coxisternal shields I–II punctate, III striate, IV smooth; sejugal apodeme obsolete; apodeme 5 interrupted medially; legs II–III without sexually-dimorphic spine-like setae; leg IV with femorogenual flange small, all leg IV setae slender, smooth.

Material examined

Holotype. 1 female, Queensland, Murarrie, 27°27'32"S 153°07'04"E, 10.xi.2011, D. Loch, ex *P. clandestinum*. Deposited in Queensland Museum (QM), Brisbane, Australia.

Paratypes. 40 females, 23 males, 21 larvae, as follows (pharate specimens not included in type material). **Australian Capital Territory:** 2 females, 2 males, 2 pharate females, 2 larvae, Commonwealth Place, Canberra, 35°17'51"S 149°08'02"E, 29.ix.2014, D. Loch, ex *P. clandestinum*. **New South Wales:** 2 females, 5 males, 1 larva, Royal Randwick Racecourse, Kensington Race Track, 33°54' 39"S 151°13'49"E, 16.vi.2014, P. McMaugh, ex *P. clandestinum*. 4 females, 1 male, Grafton Race Club, Powell St, 29°40'33"S 152°55'57"E, 22.ix.2014, P. McMaugh, ex *P. clandestinum* in mixed sward. 1 female, 1 male, 2 pharate males, 4 larvae, Rosehill Gardens Racecourse, James Ruse Drive, Rosehill, 1200 m chute outside, 33°49'21"S 151°01'47"E, P. McMaugh, ix. 2014, ex *P. clandestinum*. 3 females, 2 pharate females, 1 male, 4 larvae, New South Wales Primary Industries Office, Tocal, 32°37'51"S 151°35'31"E, 19.i.2015, N. Griffiths, ex *P. clandestinum.* 2 females, Narellan, 29.i.2015, A. Senn, ex *P. clandestinum.* **Queensland:** 6 females, 2 pharate females, 3 males, 4 larvae, Redlands Research Station, Delancey St, Cleveland, 27°31'35"S 153°14'45"E, 8.x.2014, D. Loch, ex *P. clandestinum*; 3 males, same data except xi.2014. 7 females, 4 males, 5 larvae, same data as holotype; 1 female, same data as holotype except 23.ix.2011. 1 female, Kearneys Spring Sports Complex, Ruthven St, Toowoomba, 27°36'12"S 151°56'42"E, 22.ix.2014, D. Loch, ex *P. clandestinum*. **Victoria:** 6 females, 1 larva, Yarra Valley Racing Centre, Yarra Glen, 37°39'22"S 145°23'06"E, 2.xii.2014, D. Nickson, ex *P. clandestinum*. **Western Australia:** 2 females, 2 males, Carabooda Turf Farm, 288 Carabooda Rd, Carabooda, 31°36'45"S 115°44'36"E, P. McMaugh, ex *P. clandestinum.* 3 females, 1 male, Robertson Park, Fitzgerald Rd, North Perth, 31°56'26"S 115°51'21"E, 19.x.2015, P. McMaugh, ex *P. clandestinum*. All deposited in QM except 1 female, 1 male and 1 larva from type locality deposited in Australian National Insect Collection, Canberra; and 1 female, 1 male, 1 larva deposited in United States National Museum.

Other non-type material examined. **Australia, Queensland**: 2 females, 1 larva, Upper Barron, 5.ix.1966, G.W. Saunders, ex *Pennisetum clandestinum.* 3 females, 4 males, Greenbank, Brisbane, 22.ix.1987, J. Hargraves, ex leaf sheaths *P. clandestinum*. 2 females, 2 males, 4 larvae, Numinbah Valley, 3.iii.1983, J.H. Barrett, ex *P. clandestinum*. All in QM. 1 female, Park beside East Creek, Mackenzie St, Toowoomba [Sample no. ON11/0230(11)], 27°34'47.84"S, 151°58'13.27"E, 669 masl, 13.iv.2011, D. Loch, ex *P. clandestinum*. In the Agricultural Scientific Collections Trust (ASCT), NSW.

Australia, New South Wales: 11 larvae, unknown location, R. Valder, 23.ii.1962, MC, ASCT00017735, ex *P. clandestinum*. 3 females, 1 male, 2 larvae, Rydalmere (originally from North Coast), 14.xi.1966, ASCT00017736-ASCT00017739, ASCT00017504, ex *P. clandestinum*. 14 females, 1 male, 7 larvae, Telopea, 6.i.1967 ASCT00017505-ASCT00017512, ex *P. clandestinum*. 11 females, 6 larvae, Telopea, 10.ii.1967 ASCT00017500-ASCT00017503, ex *P. clandestinum*. 3 males, Moree, 31.iii.1967, ASCT00022682, ex *P. clandestinum*. 1 larva, Taree, 31.iii.1967 ASCT00022668, ex *P. clandestinum*. 1 female, D.S.S., 17.iv.1967, ASCT000172673, ex *P.*

clandestinum. 1 female, D.S.S., 14.iv.1967, ASCT000172674, ex *P. clandestinum*. 3 females, 1 (moulting) male, 2 larvae, assoc. kikuyu yellows, Wollongbar, 13.x.1967, R. Allan, ASCT00017685, ASCT00017687, ASCT00017688, ASCT00017690, ASCT00027686, ex *P. clandestinum*. 7 females, 2 males, 1 larva, Bega, 23.ii.1970, W. Braithwaite, ASCT00017375-ASCT00017384, ex *P. clandestinum*. 8 females, 3 larvae, kikuyu yellowing, from unaffected, healthy area of paddock, Bega, 16.iii.1970, ASCT00017675-ASCT00017680, ex *P. clandestinum*. 4 females, 2 males, 1 larva, Eastwood, 21.ii.1983, P. McMaugh, ASCT00022669, ASCT00022670, ASCT00017495-ASCT00017499, ex *P. clandestinum*. 6 females, 3 males, in glasshouse 2, A.R.C. Tamworth, 9.v.1985, R. Gunning, ASCT00017515-ASCT00017518, ASCT00017526, ASCT00017527, ASCT00022661-ASCT00022663, ex *P. clandestinum*. 2 females, in assoc. with *Oligonychus digitatus*, East Maitland, 12.iii.1986, N. Griffiths, ASCT00017513, ASCT00017514, ex *P. clandestinum*. 1 female, 3 males, 4 larvae, cultivated kikuyu turf, Wellington, 27.iii.1987, V. Montgomery, ASCT00017486-ASCT00017493, ex *P. clandestinum*. All in ASCT.**Australia, South Australia**: 1 female, Unley Oval, Trimmer Terrace, Unley [Sample no. ON11/0258(10)], 34°57'01.87"S 138°36'43.01"E, 49 masl, 5.v.2011, P. McMaugh, ex *P. clandestinum*. In ASCT. **Australia, Western Australia**: 1 female, 4 Potter Way, Pinjarra [Sample no. ON11/0080(2)], 32°36'32.13"S 115°51'50.29"E, 9 masl, 8.ii.2011, P. McMaugh, ex *P. clandestinum*. In ASCT. **United States of America, California**: 2 females, 1 male, 1 larva, San Diego Convention Center, Harbor Drive, San Diego, 32°42'26-29"N, 117°09'36-55"W, 3 masl, D. Loch, ex *P. clandestinum*. All deposited in USNM, except 1 female in QM.

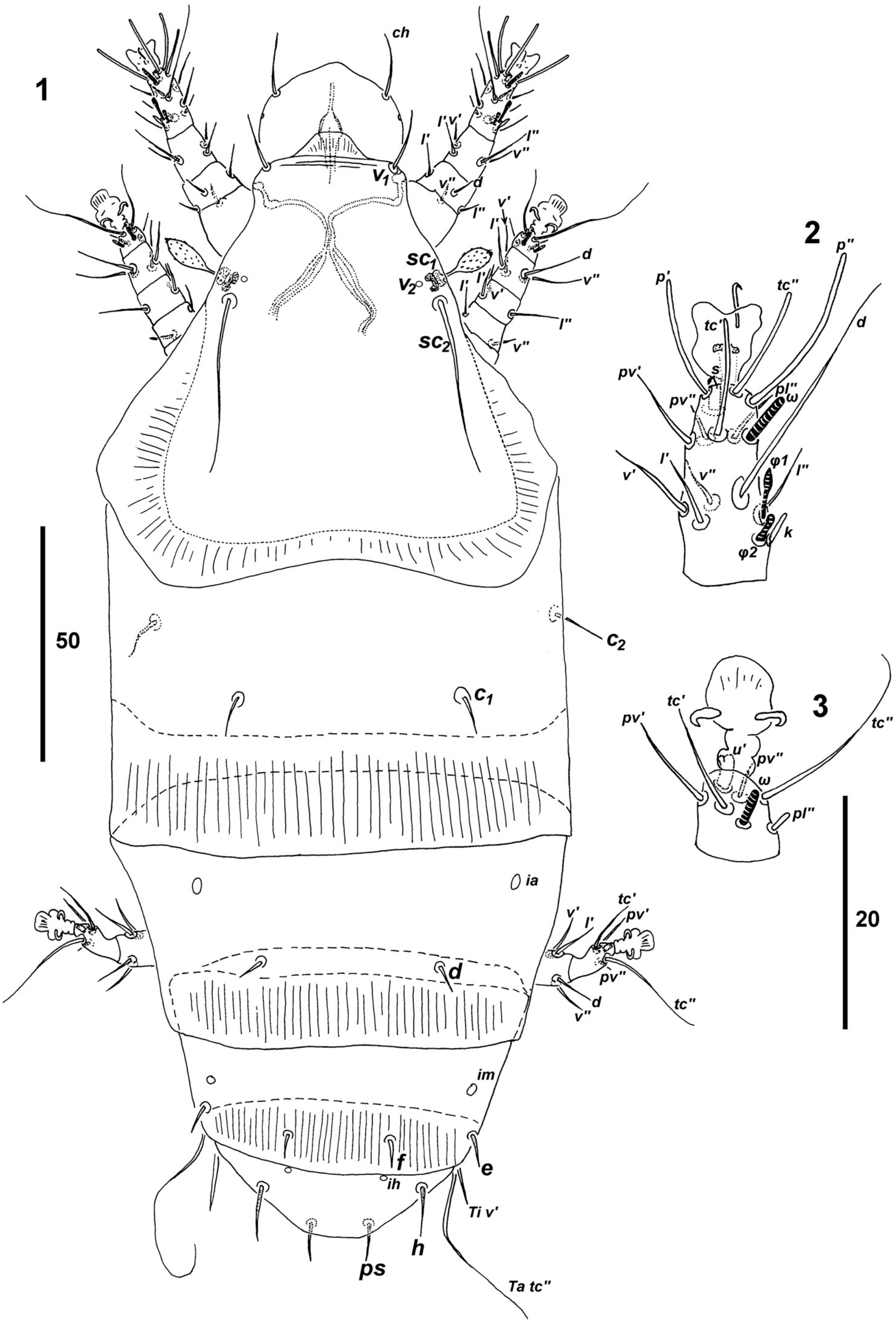
Description

ADULT FEMALE (Figs. 1–4, 13–14, 19; 41 specimens examined, 8 measured)

Gnathosoma. About as long as wide, length 34 (32–36), width 35 (32–35). Palps 9 (9–11), two-segmented, with two setae on proximal segment (apicodorsal and lateral) and distal segment with two small circular structures. Cheliceral stylets small, moderately stout, slightly curved basally, length 6 (6–8), each attached to larger cheliceral lever. Pharynx length 10 (10–12), width 5 (5–6), with thickened margins. Dorsal seta 14 (13–16), ventral seta 5 (5–7), palp coxal seta 3 (3–5), adpressed to gnathosoma.

Idiosoma. Elliptical, about twice as long as wide, length 240 (240–290), width 95 (110–140), variation partially due to flattening during slide-mounting. Prodorsal shield with weak punctate sculpturing, length 99 (97–108), with flanges posterolaterally and posteriorly, plus anterior prodorsal hood-like flange over gnathosoma; with three pairs of setae: *v1* 13 (11–16), tapering, smooth; bothridial *sc1* spiculate, capitate, length 17 (15–19), head length 11 (11–12), width 6 (5–6); *sc2* 48 (43–54); and vestigial alveolae of *v2*. Setae *sc2* located in anterior half of prodorsal shield. Distance between setae: *v1–v1* 29 (26–31), *v2–v2* 40 (36–43), *sc1–sc1* 52 (47–56), *sc2–sc2* 44 (43–50), *v1–sc2* 29 (24–32). Stigmatal opening slightly posterolaterad setae *v1*; tracheal trunks with small post-stigmatal atrium, tracheae each branching into two branches after about 30 µm of their length, branches extending posteriorly. Shields C, D, EF, H smooth. Setae *c1, c2, d, f* tapering, smooth; setae *e, h, ps* slightly thickened, with minute barbs. Setal lengths: *c1* 8 (8–11), *c2* 12 (8–14), *d* 6 (6–8), *e* 6 (6–8), *f* 7 (6–8), *h* 10 (9–12), *ps* 33 (28–35). Distance between setae *c1–c1* 49 (46–55), *c2–c2* 85 (85–104), *c1–c2* 22 (22–27), *d–d* 39 (38–46), e–e 62 (57–66), f–f 18 (17–21), *h–h*10 (9–12), *ps–ps* 33 (28–35). Cupules *ia* located anterolaterad setae *d*, cupules *im* anteriad setae *e*, cupules *ih* anteromedad setae *h*.

Coxisternal setae small, *1a* 3 (3–4), *2a* 6 (6–8), *3a* 15 (12–17), *3b* 8 (7–9), *1b* and *2b* vestigial alveolae. Distance between setae *1a–1a* 11 (11–13), *2a–2a* 16 (16–17), *3a–3a* 15 (12–17), *3b–3b* 28 (28–35). Apodemes 1 and prosternal apodeme extending beyond medial tips of apodemes 2, which just reach prosternal apodeme; sejugal apodeme present as lateral remnant, length 6–10, oriented obliquely at approximately 45°; apodemes 3 extending from trochanter III to their angulate extremities, not reaching setae *3a*; apodemes 4 present as small remnant associated with seta *3b*. Setae *1a* positioned directly below or just anterior to apodemes 1, setae *2a* positioned posterior to apodemes 2, setae *3a* anterior to apodemes 3, setae *3b* above apodemes 4. Tegula length 20 (17–20), width 18 (17–20).



FIGURES 1–3. *Steneotarsonemus hippodromus* adult female. 1, dorsal view; 2, tibiotarsus I; 3, tarsus II.

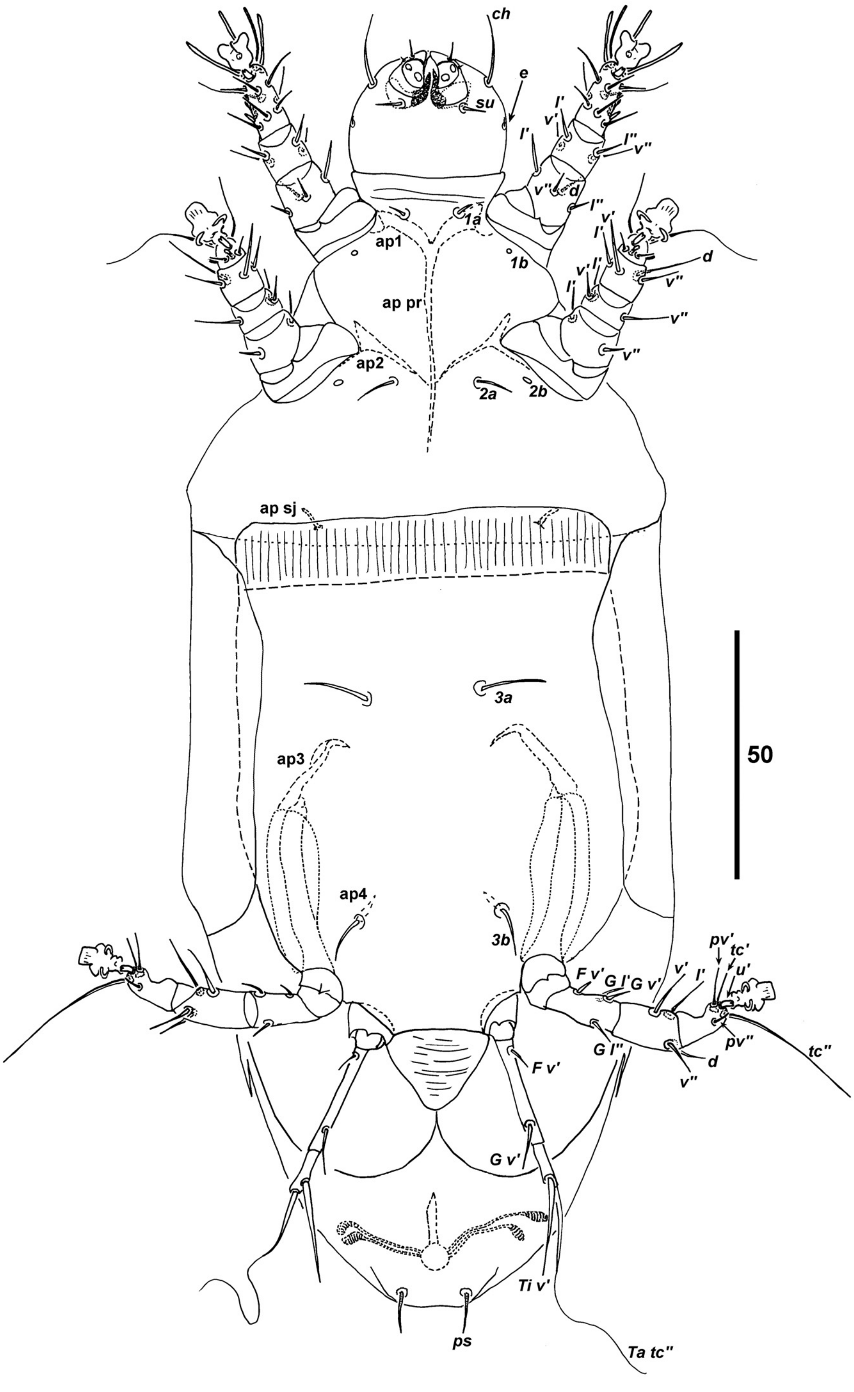


FIGURE 4. *Steneotarsonemus hippodromus* adult female, venter.

Legs. Legs short, leg IV not extending beyond idiosomal margin. Leg lengths (femoral base to tarsal tip): I 44 (44–45), II 39 (36–41), III 44 (41–48). Leg IV Fe–Ge length 29 (27–32), Ti–Ta length 9 (9–11). Tarsus II slightly longer than wide, length 8 (7–8), width 7 (6–7). Leg I with weak single claw; legs II–III with small paired claws.

Setal counts for legs I–III (femur to tarsus): 4-4-6(+2φ)+8(+ω), 2-3-4-6(+ω), 1+3-4-5. Setal measurements and form as follows.

Leg I: Femur, *d* 5 (5–6), *l′* 6 (5–7), *l″* 4 (3–5), *v″* 4 (3–6); genu *l′* 5 (4–5), *l″* 12 (8–13), *v′* 6 (4–6), *v″* 7 (5–8); tibia and tarsus fused, tibial setae *l′* 7 (5–7), *l″* 8 (7–10), *v′* 10 (7–11), *v″* 7 (5–7), *d* 18 (18–25), *k* 2 (2–3), *φ*1 elongated, length 5 (4–5), *φ*2 3 (2–3); tarsal setae *tc′* 10 (9–11), *tc″* 10 (10–12), *p′* 11 (11–13), *p″* 15 (14–16), *pv′* 8 (7–10), *pv″* 4 (4–5), *pl″* 6 (5–8), ω 5 (5), *s* spine-like, tip bifid, length 3 (3–4). Setae *(tc)* and *(p)* eupathidia. Unguinal setae absent or minute and too difficult to see (see Lindquist [1986, p. 68]) and therefore not included in setal counts.

Femur II *l′* 5 (4–6), *v″* 5 (5); genu II *l′* 4 (4–6), *l″* 11 (10–12), *v′* 5 (4–6); tibia II *l′* 7 (7–8), *d* 14 (13–18), *v′* 10 (10–13), *v″* 14 (13–17); tarsus II *tc′* 12 (10–13), *tc″* 30 (25–30), *pv′* 8 (7–10), *pv″* 4 (3–5), *pl″* spine-like, length 3 (2–3), *ω* 4 (4–5), *u′* spine-like, tip bifid, length 3 (3).

Femur III *v′* 3 (2–3); genu III *l′* 6 (4–6), *l″* 4 (3–5), *v′* 3 (3–5); tibia III, *l′* 13 (10–13), *d* 7 (7–10), *v′* 11 (11–14), *v″* 10 (8–12); tarsus III *tc′* 10 (8–13), *tc″* 35 (32–37), *pv′* 9 (6–9), *pv″* 4 (3–4), *u′* spine-like, tip bifid, length 3 (3–4).

Femur IV *v′* 4 (4–5); genu IV 9 (8–11); tibia IV *v′* 17 (17–22); tarsus IV *tc″* 70 (65–75).

ADULT MALE (Figs. 5–8, 15–16, 20; 23 specimens examined, 8 measured)

Gnathosoma. About as long as wide, length 32–38, width 31–36. Palp length 8–9. Cheliceral stylet length 8–9. Pharynx length 11–13, width 5–7. Dorsal seta 13–16, ventral seta 6–7, palp coxal seta 3–4, adpressed to gnathosoma.

Idiosoma. Length (excluding genital capsule) 165–190, width 95–135. Prodorsal plate smooth, length 67–82, width 85–105; with four pairs of setae: *v1* 14–19, *v2* 15–19, *sc1* 45–56, *sc2* 18–25. Distance between setae *v1–v1* 22–25, *v2–v2* 22–27, *sc1–sc1* 37–46, *sc2–sc2* 53–60, *v1–sc2* 43–46. Shield CD smooth, setae smooth. Setae *c1* 7–10, *c2* 15–27, *d* 12–17. Shield EF smooth, *f* 8–11, with minute barbs. Distance between setae *c1–c1* 59–77, *c2–c2* 95–125, *c1–c2* 27–43, *d–d* 28–43, *f–f* 23–29. Cupule *ia* close to seta *c1*, cupule *im* anterolaterad seta *f*. Genital capsule length 30–35, width 25–34, seta *h* 1–3, flanges present.

Coxisternal setae small, *1a* 4–5, *2a* 6–8, *3a* 9–16, *3b* 7–12; *1b* and *2b* vestigial alveolae. Distance between setae *1a–1a* 11–13, *2a–2a* 26–33, *3a–3a* 38–47, *3b–3b* 46–58. Apodemes: apodemes 2 approaching but not reaching prosternal apodeme; sejugal apodeme obsolete; apodemes 3 curving posteriorly at their distal tips, almost reaching well developed apodemes 4; apodeme 5 interrupted, probably representing separate apodeme 5 and poststernal apodeme, but furrow present along entire mid-line (Fig. 15). Coxisternal shields I–II with coarse punctations; anterior metapodosoma with coarse punctations blending into broken striate pattern on coxisternal shields III; coxisternal shields IV smooth.

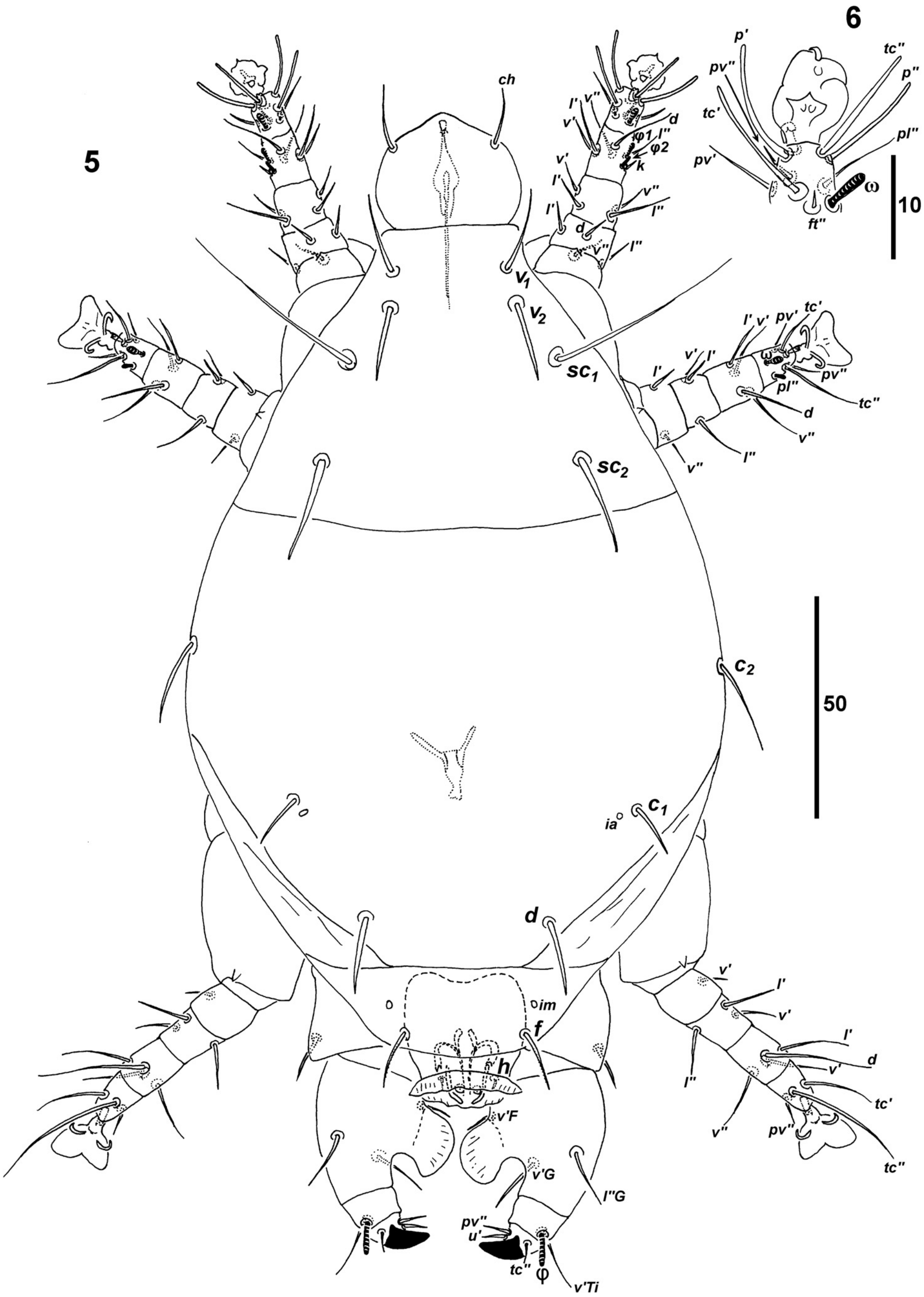
Legs. Leg lengths (femoral base to tarsal tip): I 41–48, II 41–47, III 53–60. Leg IV Fe–Ge length 34–40, width 19–30, with posterolateral flange (length 13–15, width 8–10); Ti–Ta length 13–14 (excluding claw), width 14. Tarsus II very slightly longer than wide, length 8–9, width 7–8. Leg I with weak single claw; legs II–III with small paired claws.

Setal counts for legs I–IV (femur to tarsus): 4-4-6(+2φ)-9(+ω), 2-3-4-6(+ω), 1-3-4-4. Leg IV (trochanter to tarsus), 1-1-2-1(+ω)-3. Legs I–III, setal measurements and form similar to female; tarsus I seta *ft′* absent, seta *ft″* 2; tarsus III seta *pv″* absent.

Leg IV: trochanter *v′* 8–12; femur *v′* 14–17; genu *v′* 5–6, *l″* 8–12; tibia *v′* 12–17, φ 8–9; tarsus *tc″* 5–7, *pv″* 4–5, *u′* 4–6, claw 9–11.

LARVA (Figs. 9–12, 17–18; 21 specimens examined, 7 measured)

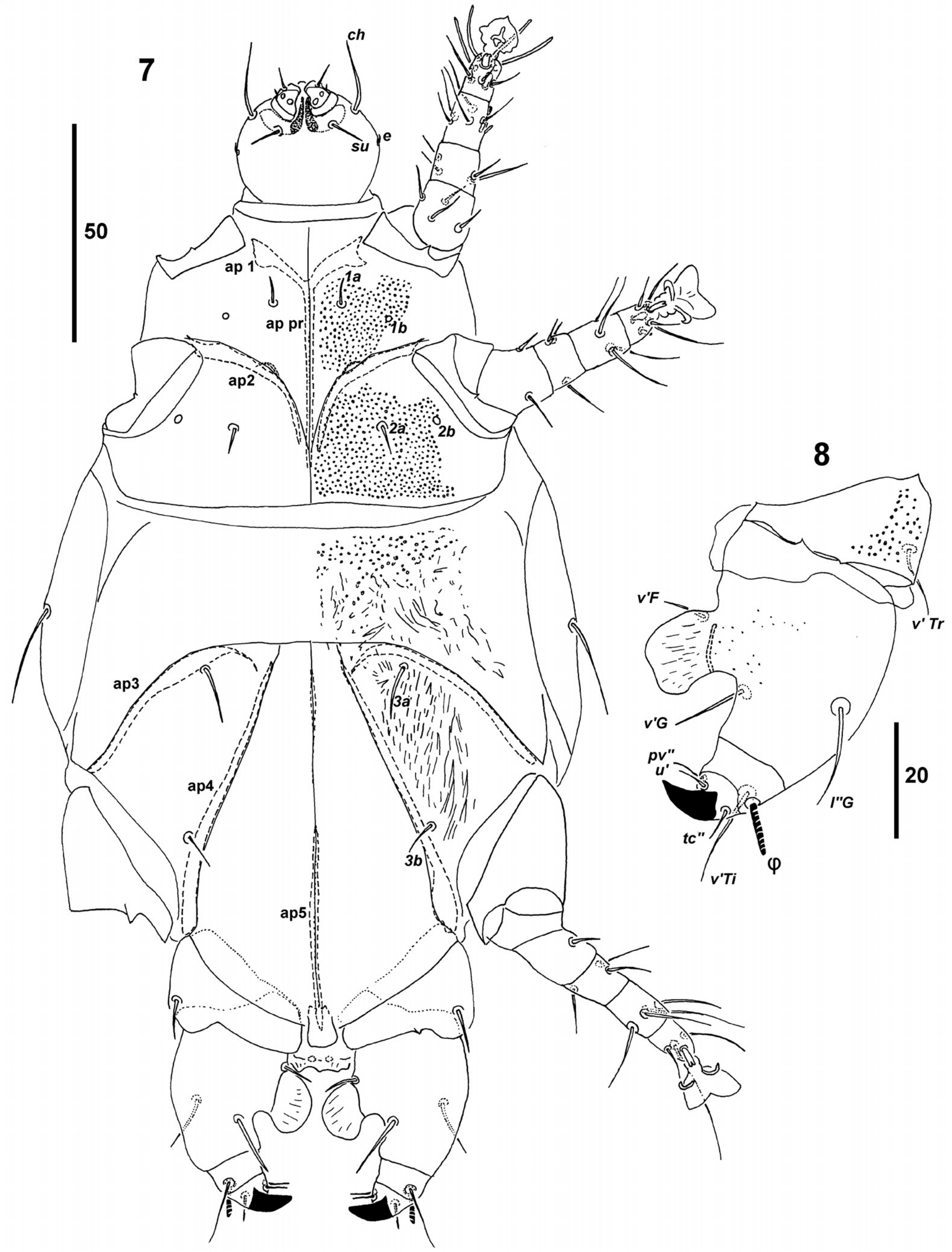
Gnathosoma. Slightly wider than long, length 26–30, width 32–34. Palp length 7–8. Cheliceral stylet length 6–8. Pharynx length 10–12, width 6. Dorsal seta 10–13, ventral seta 6–7.



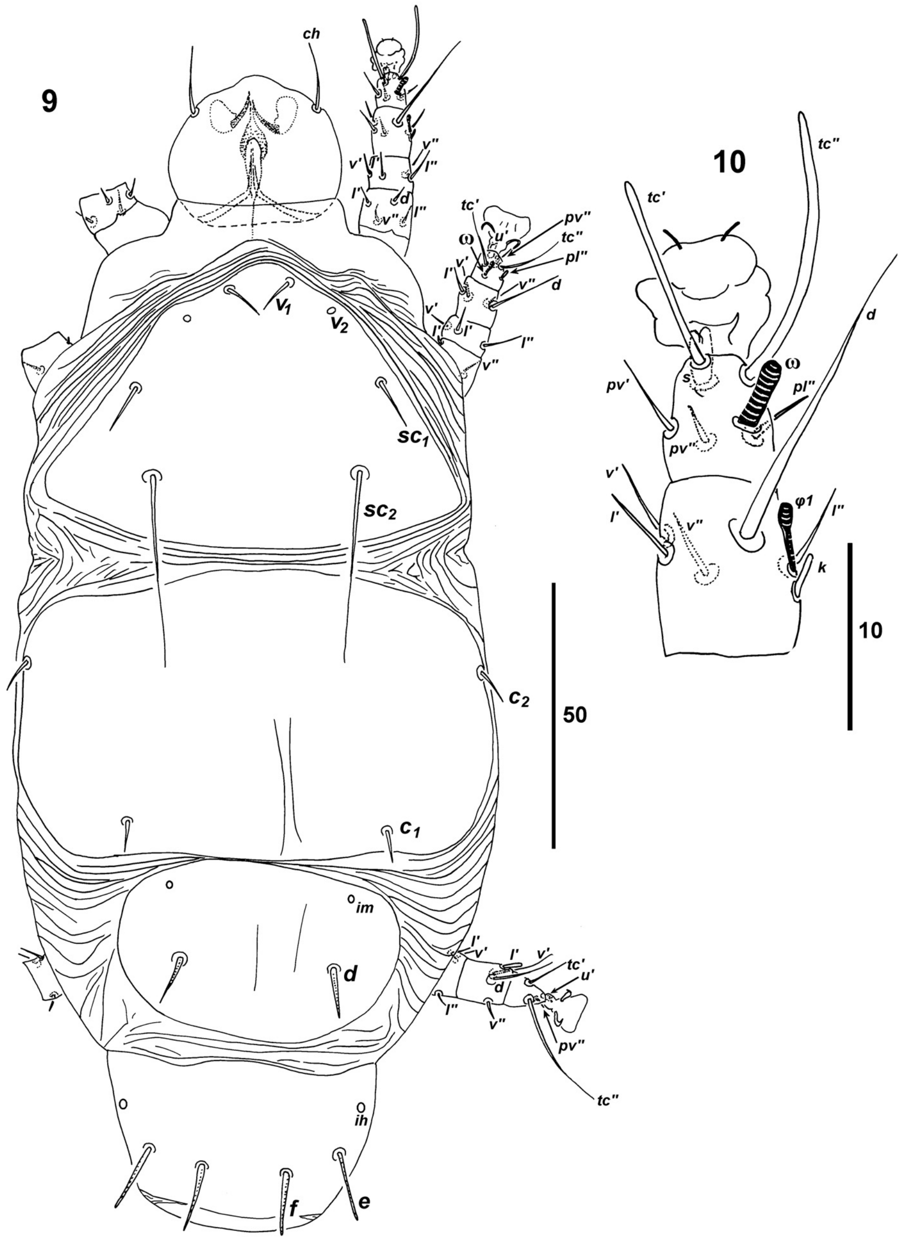
FIGURES 5–6. *Steneotarsonemus hippodromus* adult male. 5, dorsum; 6, tarsus.

Idiosoma. Length 180–260, width 75–110. Prodorsal shield smooth, 57–67 long, 72–85 wide; with three pairs of tapering, smooth setae (*v1* 6–7, *sc1* 7–9, *sc2* 27–36) and vestigial alveolae of *v2*. Distance between setae *v1–v1* 10–11, *v2–v2* 26–29, *sc1–sc1* 44–49, *sc2–sc2* 37–40, *v1–sc2* 37–39. Shields C, D, EF, HPs smooth. Setae *c1* 5–7, *c2* 7–8, smooth, *d* 8–9, *e* 12–15, *f* 12–13, *h1* 15–16, *h2* 13–17, weakly barbed, *ps1* 3–4, *ps2* 4–5, fine, smooth. Distance between setae *c1–c1* 45–51, *c2–c2* 77–86, *c1–c2* 31–34, *d–d* 27–30, *e–e* 32–36, *f–f* 13–15, *h2–h2* 22–25. Cupules *im*, *ih* present; cupules *ia* absent or indistinct. Coxisternal setae small, *1a* 4–5, *2a* 4–5, *3a* 7–10, *3b* 5–6; *1b* and *2b* vestigial alveolae. Distance between setae *1a–1a* 13–14, *2a–2a* 23–28, *3a–3a* 26–38, *3b–3b* 24–47 (distended). Longitudinal striae present between coxisternites III.

Legs. Leg lengths (femoral base to tarsal tip): I 33–38, II 33–35, III 33–35. Leg I with rudimentary claws; legs II–III with small claws. Setal counts for legs I–III (femur to tarsus): 4-4-6(+2φ)-6(+ω), 2-3-4-5(+ω), 1-3-4-4.



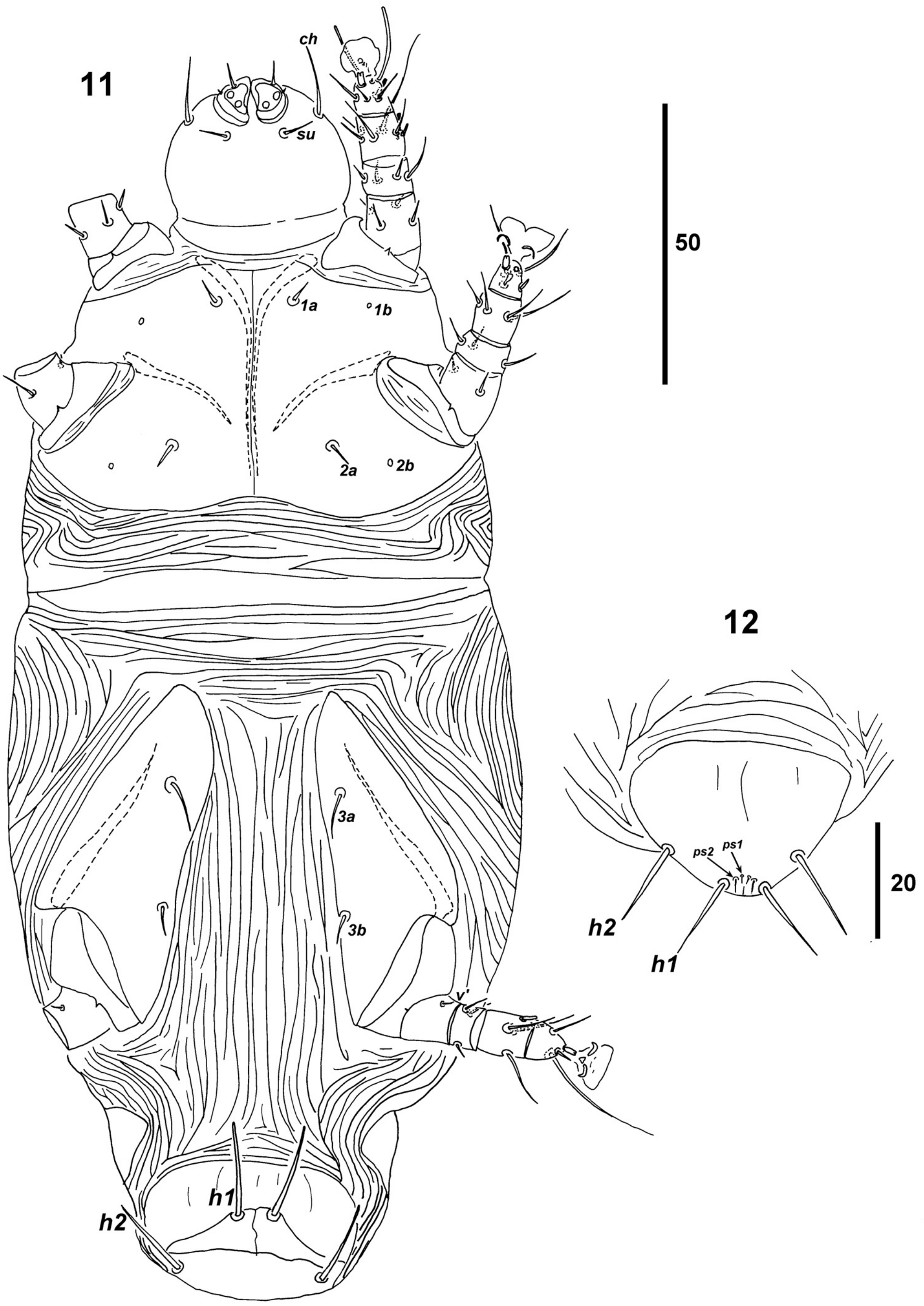
FIGURES 7–8. *Steneotarsonemus hippodromus* adult male. 7, venter; 8, leg IV, dorsal view, different specimen.



FIGURES 9–10. *Steneotarsonemus hippodromus* larva. 9, dorsum; 10, tibia and tarsus I.

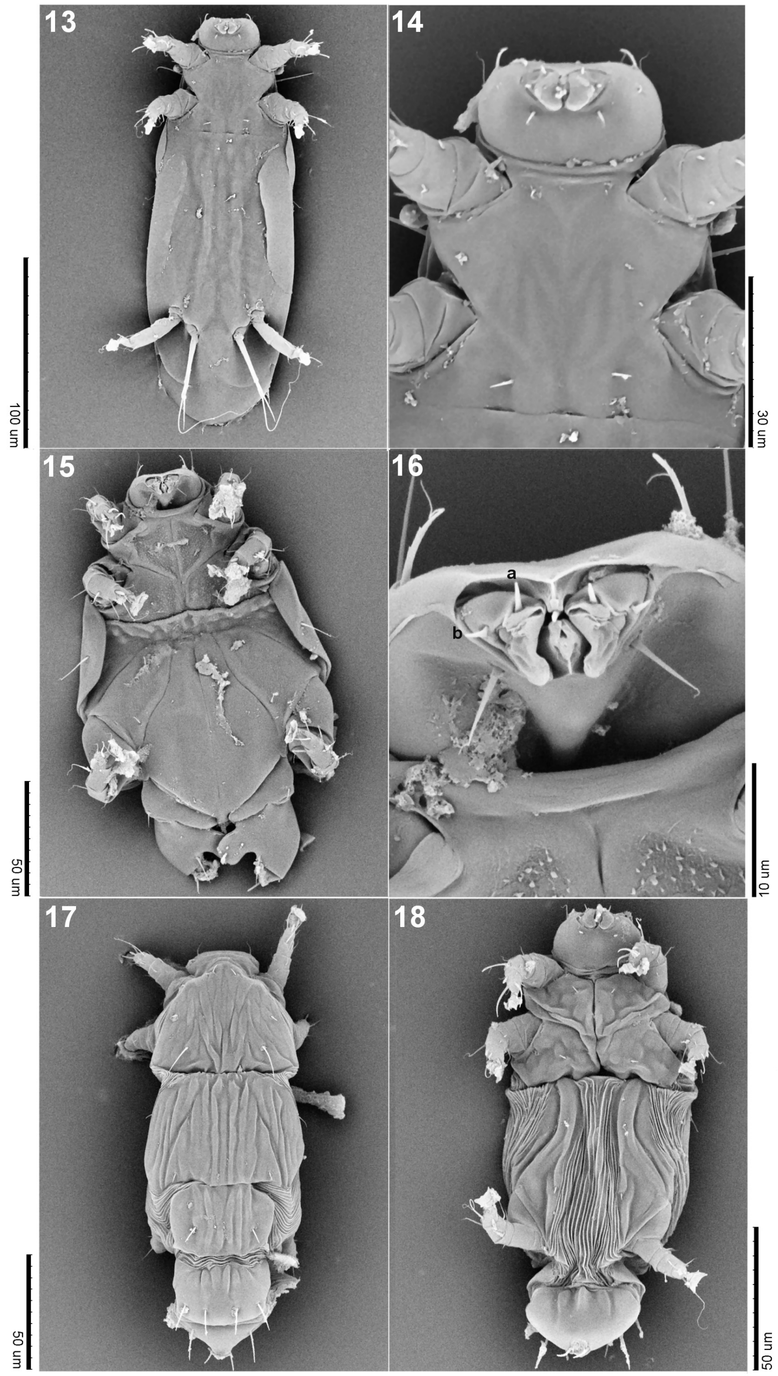
Etymology. The specific name *hippodromus* refers to a horse-racing course, a hippodrome, because the new species has been found on every kikuyu grass race-course sampled thus far in Australia.

Distribution. This new species is widespread in Australia, so far being found anywhere where kikuyu grass is grown and should not be regarded as a mite species of biosecurity concern. As this grass is native to east Africa, and is of economic importance in many countries, either as a useful turfgrass or a weed, this species could have a global distribution. This point is further emphasised by our recent collection of *S. hippodromus* in California.



FIGURES 11–12. *Steneotarsonemus hippodromus* larva. 10, venter (caudal cone folded); 11, caudal cone, not folded.

Differential diagnosis. *Steneotarsonemus (Steneotarsonemoides) hippodromus* **sp. nov.** is most similar to *S. porrectus* in sharing much reduced sejugal apodemes (as opposed to larger, crescent-shaped sejugal apodemes in other species) and having coxisternal setae *2b* positioned posterior to apodeme 2 (as opposed to directly under apodeme 2 in other species). *Steneotarsonemus* *hippodromus* differs from *S. (S.) porrectus* in: apodeme 4 reduced to minute remnant (compared with almost reaching mid-line in *S. porrectus*); and coxisternal seta *3a* positioned well anterior of apodeme 3 (compared with *3a* positioned at about anterior level of apodeme 3 in *S. porrectus*). Species of *Steneotarsonemus (Steneotarsonemoides)* can be identified in key provided.



FIGURES 13–18. *Steneotarsonemus hippodromus*. Female: 13, venter; 14, anteroventer. Male: 15, venter; 16, gnathosoma (a = dorsal seta on proximal palpal segment; b = lateral seta on proximal palpal segment). Larva: 17, dorsum; 18, venter.

The scanning electron micrographs (Figs. 13–18) show some features that cannot be seen easily under the compound microscope. Firstly, furrows demarcating the line of fusion between the coxisternae are absent on the adult female (Figs. 13–14) but are present in the male (Fig. 15) and on the propodosomal venter of the larva (Fig. 18). Secondly, the palpal structures are also difficult to discern, but the form in the male—with a dorsal and posterolateral seta on the proximal palpal segment (Fig. 16)—is present in all life stages. Finally, the sculpturing of the dorsal and ventral shields (Figs. 17–18) in the larva is not as distinct in slide mounted specimens, particularly on the prodorsal shield. This could be an artefact of slide-mounting, or of the preparation techniques for SEM, which can cause shrivelling of soft-bodied animals.

Thus far, *S. hippodromus* is host-specific, and was not found on other common species of turf grasses, especially *Cynodon* spp., *Digitaria didactyla*, *Sporobolus virginicus*, *Stenotaphrum secundatum* and *Zoysia* spp., which were sampled recently in a survey of mites associated with turfgrasses (McMaugh *et al.* 2016).

Key to species of *Steneotarsonemus (Steneotarsonemoides)* (females)

This key is adapted from the key presented in Mitrofanov & Sharonov (1988).

1. Remnants of sejugal apodeme in the form of minute spots; sternal setae *2b* positioned posterior to apodeme 2. 2

– Remnants of sejugal apodeme in the form of elongate strands; sternal setae *2b* positioned directly under apodeme 2. 3

2. Apodeme 4 almost reaching mid-line of body; coxisternal seta *3a* positioned at about anterior level of apodeme 3. Hosts: *Deschampsia cespitosa, Poa pratensis*. Country: Russia. . . . . *S. (Steneotarsonemoides) porrectus* Livshits *et al*., 1981

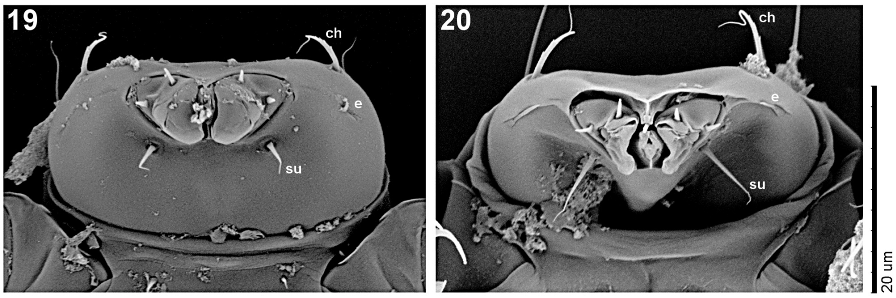
– Apodeme 4 reduced to minute remnant; coxisternal seta *3a* positioned well anterior of apodeme 3. Host: *Pennisetum clandestinum*. Country: Australia. . . . . *S. (Steneotarsonemoides) hippodromus* **sp. nov.**

3. Prosternal apodeme fragmented in posterior half, apodemes 2 not coming close to prosternal apodeme. Hosts: *Triticum, Poa.* Countries: Kazakhstan, Russia, Ukraine. . . . . *S. (Steneotarsonemoides) panshini* Wainstein & Beglarov, 1968

– Prosternal apodeme entire, apodemes 2 coming close to or connected with prosternal apodeme. 4

4. Setae *3a* not reaching base of seta *3b*; seta *sc2* extending past posterior margin of prodorsal shield. Hosts: Poaceae, *Cornus mas*. Country: Ukraine. . . . . *S. (Steneotarsonemoides) azureus* Mitrofanov & Sharonov, 1988

– Setae *3a* extending past base of seta *3b*; seta *sc2* not reaching posterior margin of prodorsal shield. Host: Poaceae. Country: Russia. . . . . *S. (Steneotarsonemoides) cerinus* Mitrofanov & Sharonov, 1988



FIGURES 19–20. *Steneotarsonemus hippodromus*. Female: 19, gnathosoma. Male: 20, gnathosoma. *ch* = dorsal gnathosomal (cheliceral) seta; *e* = palpcoxal seta; *su* = ventral gnathosomal (subcapitular) seta.

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Phytophagous mite species affecting *Cynodon* spp. (bermudagrasses) and *Pennisetum clandestinum* Hochst. ex Chiov. (kikuyugrass) in Australia

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Abstract

Warm-season turf-grasses in Australia were first recognized as being infested by plant-feeding mites over 80 years ago but the identities of the species involved remained unresolved. There had long been an underlying assumption (based mainly on overseas literature) that mites of the family Eriophyidae were likely responsible for the distorted growth frequently seen and attributed to mite damage. A survey during the 2010/11 growing season followed by opportunistic sampling over the next 5 years revealed the presence of at least two eriophyoid mites: *Aceria cynodoniensis*, which was already known from Australia and *Abacarus cynodonis,* a previously unrecorded species. Importantly, the tenuipalpid species, *Dolichotetranychus australianus*, was also confirmed as a substantial contributor to mite damage symptoms seen on *Cynodon dactylon* and *C. dactylon X transvaalensis* (bermudagrasses). In addition, a new tarsonemid, *Steneotarsonemus hippodromus* Seeman et al., was found extensively on *Pennisetum clandestinum* (kikuyugrass) in both turf and pasture plantings. Grass-webbing spider mites, *Oligonychus araneum* and *Oligonychus digitatus* (Tetranychidae), also occasionally affect these and a wide range of other warm-season grasses non-selectively in Australia. This paper reviews the identities of the mite species listed above, including their putative origins, distribution and damage symptoms, together with implications for turf producers and facility managers. Additional taxonomic detail on the two eriophyoid species studied is also provided.

Key Words: *Aceria, Abacarus, Dolichotetranychus, Steneotarsonemus*, *Oligonychus*, *Cynodon* spp., *Pennisetum clandestinum*, turfgrasses, turf management

Introduction

Turfgrass use in Australia is dominated by warm-season species, which accounted for approximately 85% of production turfgrass in a national survey conducted in 2006 (Haydu et al., 2008; Aldous et al., 2009). Within the warm-season turfgrasses, the 'big three' – *Cynodon* spp. (bermudagrasses, known as green couchgrasses in Australia – 44%), *Stenotaphrum secundatum* (St Augustinegrass – 32%), and *Pennisetum clandestinum* (kikuyugrass - c. 15%) – dominate the production sector and collectively represent around 90% of warm-season turfgrass sales. While other well adapted and widely naturalized species reduce their contribution in established turf areas, any pest or pest group that affects one or more of the commercially grown warm-season turfgrasses clearly has important implications for the Australian turfgrass industry, both at the production and at the facility management levels.

In this context, the effects of mites on warm-season turfgrasses in Australia has long been a contentious, misunderstood, confused and poorly documented topic. Eriophyoid mites were first observed on *Cynodon dactylon* (L.) Pers. in Western Australia over 80 years ago by Newman (1934) and tentatively reported in the literature as *Eriophyes tenuis* (Nalepa). Subsequently, Gibson (1967) in New South Wales (NSW) made the next published report (usually, but perhaps erroneously, cited as the first report) from Australia of eriophyoid mites on *C. dactylon* based on specimens identified by H.H. Keifer as *Aceria neocynodonis*, 1960, now regarded as a synonym of *Aceria cynodoniensis* Sayed, 1946 (Acari: Eriophyoidea: Eriophyidae). This is the 'bermudagrass mite' reported from the USA (e.g. Keifer, 1960; Keifer et al., 1982) as causing damage to *C. dactylon* and *C. dactylon* (L.) Pers. *x transvaalensis* Burtt Davey. Prior to this, Womersley (1943) had described a flat-mite, *Dolichotetranychus australianus* (Acari: Tetranychoidea: Tenuipalpidae), from an infestation found on a *C. dactylon* bowls green in southern Queensland. From references in the extension and popular literature by Champ (1961) and McMaugh (1986), it would appear that this second mite species found on *C. dactylon* was reasonably well known for a time. In this regard, *D. australianus* has since been redescribed by Seeman et al. (2016a) based on new Australian material collected from *C. dactylon* and *C. dactylon* × *transvaalensis* over the last few years.

Prior to this most recent work, the only mite mentioned in the turf literature or taught in educational courses in Australia was almost universally assumed to be the "couch grass mite", *Ac. cynodoniensis*, based on American literature for this species spanning the past 50 years or so. Moreover, because mites, especially eriophyoids, are extremely small and very difficult to see in dissected plant material without adequate magnification, their presence in the field is almost always determined indirectly by the visual damage symptoms they cause in affected plants.

Brief mention of an unnamed tarsonemid mite (Acari: Tarsonemidae) on *Pennisetum clandestinum* Hochst. ex Chiov. (kikuyugrass) in Australia was made by Allen (1967). However, while additional specimens had been collected over the years and lodged in reference collections, there was no further information about them until recently following their identification and description as a new species, *Steneotarsonemus hippodromus*, by Seeman et al. (2016b).

Plant-feeding mite infestations distort the shoots and lead to slower turfgrass growth through poor lateral stolon extension and a subsequent lack of turf strength through reduced matting of stolons and poor root development. In the case of production turf, this results in sod breaking up or tearing on the harvest conveyer leading to a loss of harvested product which anecdotally can reach 30% or more. Where mite infestations are lighter, allowing intact turf rolls to be harvested, this then transfers the problem to the turf buyer. Managers of established turf facilities (sports fields, parks, golf courses, bowls greens, race tracks, etc) face two major issues in the event of a mite outbreak at their facility: firstly, reduced use due to poorer wear-resistance allied with the extremely slow recovery from wear of the mite-affected turf; and, secondly, the poor quality and uneven nature of the turf surface through distortion and thinning caused by mites.

Despite the significant damage that can be caused by mites to turfgrass surfaces, their presence is often not recognized, leading to ineffective solutions to other perceived problems being implemented. Up until now, it was unclear which mite species and how many different mite species were infesting the various warm-season turfgrasses in Australia. Without proper documentation, effective control measures for different situations could not be devised. This was the catalyst for an extensive survey in 2010/11. This was the starting point for providing definitive answers with further sampling through to 2016 which also included taxonomic studies. A preliminary account of this work, with family and genus level mite identifications, was presented at the 3rd International Horticulture Congress in 2014, and included information on additional minor grass species (McMaugh et al., 2016). This present paper covers only the major grass taxa, *C. dactylon* and *C. dactylon* × *transvaalensis* and *P. clandestinum*, for which detailed identifications of the phytophagous mites found have now been completed. We note that further investigations are warranted in relation to mites associated with *Zoysia* spp. However, these have been deferred pending the collection of additional specimens of *Dolichotetranychus* and detailed morphological comparisons involving the *Aceria* species which was found.

Materials and Methods

In the course of our initial one-year survey during the 2010/11 growing season, 68 samples from *Cynodon* spp. and *P. clandestinum* from 48 sites were examined for the presence of mites in the laboratory at Orange, NSW. Sampling was conducted in most Australian states and territories (with the exception of Tasmania and the Northern Territory). Because mites tend to be spread unevenly over an area with “hot spots” showing where an infestation is concentrated, ad-hoc samples were taken from where and when visual symptoms of mite damage were seen. GPS coordinates for each collection site were later confirmed on Google Earth using the physical address, and photographs were taken of the damage symptoms observed. Field samples were wrapped in damp paper, placed in zip-sealed plastic bags, and refrigerated prior to sending to the laboratory by an express postal service. Prior to transportation, some fresh plant samples were also dissected directly under a stereomicroscope (50X magnification) which facilitated photographs of the mites and their eggs. Overall, samples were collected from turf production farms and other country sites (38%), urban open space including parks, roadsides and lawns (40%), sports (13%) and research facilities (9%).

On arrival in the laboratory, plant samples were placed separately into screw-capped plastic containers with 70% ethanol and shaken for approximately 2 min to extract any mites hidden in the foliage; usually, the plant material was partially macerated beforehand to assist in the release of mites. Samples were then vacuum-filtered. For this process to be effective, it was essential to limit soil contamination during sample collection to prevent mites from being obscured during examination. Filtered samples were then examined under a stereomicroscope and mites identified to family and genus level as far as possible.

Representative specimens were slide-mounted in Hoyer's medium (Krantz, 1978) for further detailed examination under a compound microscope equipped with phase contrast (Olympus BX50). Identifications of the eriophyoid mites to species level (as discussed here) were made by using the keys provided by Amrine et al. (2003) in addition to the published descriptions of *Aceria cynodoniensis* by Sayed (1946) and *Aceria neocynodoniensis* by Keifer (1960). The identification of *Abacarus cynodonis* was based on the original description and illustrations provided by Abou-Awad & Nasr, 1983 in addition to publications by Smith-Meyer (1989) and Wang et al. (2014) which report the presence of this species from Africa and Saudi Arabia, respectively.

Subsequent to our initial 2010/11 survey, a further a further 194 samples of *Cynodon* spp. (124) and *P. clandestinum* (70) from 126 sites, 98 of which were new collection sites, have been examined through until 2015/16, mostly in specialist acarology laboratories in South Brisbane, Queensland (QLD) and Orange (NSW). There was also some repeat sampling at older collection sites over time. Extraction methodology was similar to that described above, though greater use was also made of direct examination through dissection of fresh samples under a stereomicroscope. Any variations in methodology are detailed below.

Identifications of eriophyoid mites to species level were made by using the keys provided by Amrine et al. (2003) in addition to the published descriptions of *Aceria cynodoniensis* by Sayed (1946) and *Aceria neocynodoniensis* by Keifer (1960). The identification of *Abacarus cynodonis* Abou-Awad & Nasr, 1983 was based on the original description and illustrations in addition to publications by Smith Meyer (1989) and Wang et al. (2014), which reported the presence of this species from Africa and Saudi Arabia, respectively.

The hypothesis that *D. summersi* and *D. australianus* represent the same species was tested by examining type specimens of *D. summersi* and type specimens, historic collections and fresh material of *D. australianus*. New specimens of *D. australianus* were removed from under sheaths of infested *Cynodon* spp., killed in 75% ethanol, mounted in Hoyer's medium, and examined at a magnification of 1000× using a Nikon Eclipse 80i microscope equipped with Nomarski optics and a drawing tube. Specimens for measurement were selected after examining all available material and choosing from this a subsample of good-quality specimens from several localities and representing different body sizes. Further details regarding measurements taken are included with the taxonomic re-description by Seeman et al. (2016a).

Tarsonemid mites were collected from *P. clandestinum* by stripping leaf blades and sheaths, and shaking them for one minute in 50 mL of 75% ethanol, which was then drained through a sieve into a petri dish, allowed to settle, and examined. Some mites were also removed directly from grass, with the aid of a stereomicroscope, where they formed small colonies close to the node, often just under the sheath. Specimens were cleared in Nesbitt's fluid, slide-mounted in Hoyer's medium and examined with a Nikon Eclipse 80i microscope as described above. A subsample of good-quality specimens from several localities and representing different body sizes were selected for measurement after examining all available material and choosing from this. Further details regarding measurements taken are included with the taxonomic description by Seeman et al. (2016b). Specimens for scanning electron microscopy were dehydrated with Hexamethyldisilazane, sputter-coated with gold, and examined in a Hitachi TM-1000 Tabletop microscope.

Results

Notes on methodology

Phytophagous mites were extracted from 43% of the 68 samples in the initial 2010/11 survey. With improved sampling and handling together with greater experience in recognising the external symptoms of mite infestations, phytophagous mites were successfully recovered from 76% of the 194 samples examined subsequently (95% of *Cynodon* spp., 76% of *P. clandestinum* samples, respectively).

Bermudagrass/Green Couchgrass

Two main mites were identified from *Cynodon* spp.: *Dolichotetranychus australianus* and *Aceria cynodoniensis*. For *C. dactylon* and *C. dactylon x C. transvaalensis* collectively, the number of survey samples containing phytophagous mites was almost evenly divided between *Ac. cynodoniensis* (Eriophyidae) and *D. australianus* (Tenuipalpidae), 8 and 9 samples respectively from a total of 40. A similar trend continued in subsequent sampling, with mixed tenuipalpid-eriophyoid populations found in 31 cases; note also the co-habitation of these two species in Egypt which was reported by Sayed (1946). These co-infestations were usually dominated by one or other mite species (9 by *Ac. cynodoniensis*, 15 by *D. australianus*). It is also perhaps noteworthy that neither mite species was recorded in our work on straight C. transvaalensis, nor are there any reports of any such infestations in the literature.

The visual symptoms (i.e. the distorted growths, or galls) caused by infestations of *Ac. cynodoniensis* and *D. australianus* are subtly different (Plates 1 and 2, respectively). Witch's brooms (rosetted growths at stolon nodes – see also Keifer et al., 1982) and poor stolon root development are typical of *Ac. cynodoniensis* infestations, which tend to be concentrated more along the edges rather than being spread across an area. At the same time, individual growths within an *Ac. cynodoniensis* witch's broom become shortened with leaves greatly reduced in length, thickened and flattened laterally to give a 'pinetree' effect. *D. australianus* on the other hand, produces a characteristic thinning and weakening of the stand, usually concentrated in patches, but frequently spread across an infested area rather than being prevalent along the margins. There is markedly less proliferation of distorted growths at stolon nodes (i.e. no strong witch's brooming), and these pinetree-like growths are slightly more thickened and rounded with even shorter leaves than for *Ac. cynodoniensis*. *D. australianus* can also persist in some much older, elongated pinetree-like growths (e.g. Plate 2(e)), though not as prevalent as in younger, fresher growths. In the case of mixed *Aceria-Dolichotetranychus* populations, the external symptoms tended to follow the more dominant species.

(Insert Plates 1 and 2 near here)

Populations of *Ac. cynodoniensis* and *D. australianus* could be exceptionally high in massively distorted growths, providing those aberrant structures had not yet been browned or killed by the mites. Counting each individual mite present was impractical, but 11 samples had well over 10,000 mites (5 with *Ac. cynodoniensis,* 6 with *D. australianus*). A further eight samples had an estimated 1,000-10,000 eriophyoid mites and six samples had a similar number of flat mites; of these only one sample had both > 1,000 eriophyoid and flat mites.

During our initial survey, a single specimen of *Abacarus cynodonis* (Eriophyidae) was collected from Perth, Western Australia (WA). This has since been determined as a previously unrecorded mite species in Australia. Two further collections of this species were subsequently located among national records and stored specimens, one from Sydney (NSW) in 2009 and the other from Townsville (QLD) in 2011.

Eriophyoid Bermudagrass Mite Taxonomy (to be completed by first author)

Eriophyinae Nalepa, 1898

Aceriini Amrine & Stasny, 1994

Aceria cynodoniensis Sayed, 1946. Confirmation of species from Australia

Type data.

Geographic distribution.

Relation to the host plant.

Material examined (distribution in Australia). (List some of the material plus insert an image of the mite, if possible).

Anthocoptini Amrine & Stasny, 1994

Abacarus cynodonis Abou-Awad & Nasr, 1983. New record. (Fig. ? [insert photo, if possible]

Abacarus cynodonis Abou-Awad & Nasr, 1983: 183-185

Abacarus cynodonis; Meyer, 1989:421-422

Abacarus cynodonsis; Amrine & Stasny, 1994:1 (species name misspelt)

Abacarus cynodonsis; El-Halawany, 2012:212

Abacarus cynodonsis; Wang, El-Halawany, Xue and Hong:422-424 (species name misspelt)

Material examined. (to be added)

Type data. *Cynodon dactylon* (L.) Pers., bermuda grass (Poaceae); Sinai Peninsula, Egypt.

Relation to the host plant. On upper leaf surface, possibly causing leaf curl in combination with other mites.

Other plant hosts. *Sesuvium portulacastrum* (L.) L. (Aizoaceae); *Elymus repens* (L.) Poaceae

Known distribution. Egypt, Africa, Saudi Arabia.

Kikuyugrass

Mites from *P. clandestinum* in Australia were determined to be a new species of *Steneotarsonemus* (Tarsonemidae) from the subgenus *Steneotarsonemoides*. This species was recently described as *Steneotarsonemus hippodromus* by Seeman et al. (2016b). Members of this genus are phytophagous and several species are pests (e.g. Hummel et al., 2009). Note that superficially, *Steneotarsonemus* and *Dolichotetranychus* mites can appear similar in size and shape when preserved plant material is quickly scanned under the stereomicroscope, particularly since the characteristic reddish color of the *D. australianus* mites can be lost through storage in 70% ethanol. This problem may have accounted for some apparent misidentifications during our initial survey (McMaugh et al., 2011). Subsequently, however, we recorded adult female *D. australianus* mites on *P. clandestinum* on only two occasions out of a total of 53 samples (post-survey 2011-2016) with mites present; this occurred when *P. clandestinum* was growing amongst, or in close proximity to, infested *C. dactylon*, and tarsonemid mites were also present on both occasions (Seeman et al., 2016a; McMaugh et al., 2016). However, rather than being indicative of *P. clandestinum* as a preferred host with a resident population, these results are more suggestive of migratory behaviour, with *D. australianus* females moving from the associated *C. dactylon* to establish new colonies under less crowded conditions.

Tarsonemid mites were present in 32 out of 45 samples taken between 2014 and 2016, with an average of 24 ± 4.2 mites per infested sample (range 1-85). The condition of grass explained a significant proportion of the variation ($R^2 = 0.22$, $F(1, 35) = 9.77$, $P < 0.01$), with more mites being found on grass in good condition. Only one mite was found from five samples in poor condition. Perhaps significantly also, the numbers of *S. hippodromus* seen through dissection or recovered by filtration were perceived to be appreciably fewer than for *D. australianus* infesting bermudagrass (McMaugh and Loch, 2015; McMaugh et al., 2016).

The visual damage symptoms see in *P. clandestinum* infested with tarsonemid mites varied somewhat between long-cut or uncut grass and short-cut turf (Plate 3). These included poor root development, shortening of the internodes and a proliferation of side shoots along the elevated stolon. Individually, heavily infested shoots were shorter and thicker, giving a clubbed-like appearance along with the possible bleaching of leaves.

(Insert Plate 3 near here)

Discussion

Within the animal kingdom, mites (Subclass: Acari) are second only to the insects in terms of species diversity, but only about 5% of the estimated >1 million mite species have been described so far (Walter, 2006). It is therefore not surprising that a previously undescribed mite species, *S. hippodromus* and previously unrecorded species, *Ab. cynodonis*, are present on turfgrasses in Australia along with other already known species.

Warm-Season Turfgrass Mites in Australia

In Australia, the phytophagous mites recorded on *Cynodon* spp. and *P. clandestinum* turfgrasses to date come from four different families, namely Eriophyidae, Tenuipalpidae, Tarsonemidae and Tetranychidae. The first three families were examined in this study, which asked the question: which species within the specified mite genera is/are responsible for the damage to the various grasses? The Tetranychidae were rare throughout our study, but are also discussed briefly below by way of completeness.

Essentially, all of the mite species from the three main groups studied are found Australia-wide: wherever their host species will grow (Plate 4). For this reason, *S. hippodromus* is mainly found through the southern half of Australia because *P clandestinum* is only grown in highland areas in northern part of the continent.

(Insert Plate 4 near here)

1. Eriophyidae. *Aceria cynodoniensis*. During our initial 2010/11 survey, eriophyoid mites suspected to be *Ac. cynodoniensis* were extracted from samples of *Cynodon* spp. In Australia, the identity of *Ac. cynodoniensis*, a species of major concern on *Cynodon* spp. worldwide, is now confirmed based on more recently collected samples (including specimens from San Diego, USA) and historic data.

This mite was originally described by Sayed (1946) from infestations found in Egypt. It has since been reported from many other parts of the world, including South Africa (Meyer, 1968; Smith Meyer, 1981a, 1981b), the USA (initially as *Ac. neocynodonis*), Zimbabwe (Goldsmid 1964), Greece (Kapaxidi et al., 2008) and Saudi Arabia (Wang et al., 2014). Although Gibson's (1967) collection from NSW is regarded as the first official record of this species from Australia, as mentioned earlier, there is a much earlier record in the literature by Newman (1934) whereby the symptoms of a similar witch's brooming effect on *C. dactylon* in Western Australia are described. In USA, it occurs across all of the southern states including Arizona, California (Keifer, 1960; Tuttle and Butler, 1961), Florida (Denmark, 1964; Johnson, 1975), Georgia (Davis, 1964; Barke and Davis, 1971), Nevada, New Mexico, Oklahoma and Texas (Reinert, 1982; Reinert et al., 1978, 2004, 2008). However, it is not listed in the checklist prepared by Xue and Zhang (2009) as having been recorded in South-East Asia.

The main plant host for Ac. cynodoniensis is *C. dactylon* but it has also been recorded widely on *C. dactylon x transvaalensis* and on *Cynodon incompletus* (Meyer, 1968; Smith Meyer, 1981a; Wang et al., 2014), which was supported by one sample from *C. incompletus* in our current work. Smith Meyer (1981a, 1981b) also reported *Ac. cynodoniensis* as having been recorded on *P. clandestinum* in South Africa, though this must be regarded as doubtful unless independently verified. It inhabits the terminal leaf sheaths of the grass which leads to profound stunting and a witch's brooming effect followed by plant decline.

Early acarologists such as Butler (1963) believed that the bermudagrass mite, *Ac. cynodoniensis*, is native to Africa. More recently, suggestions in the American literature (e.g. Reinert, 1982; Williamson et al., 2013) have implied that *Ac. cynodoniensis* is probably native to Australia.

However, without any supporting evidence in such publications, this does not fit well with the presumed centre of origin for the grass species, *C. dactylon*, which is located in the Middle East with a widespread distribution throughout Africa (Harlan and de Wet, 1969), nor with the fact that most (if not all) *Cynodon* genotypes in Australia are derived from recent imports (Langdon, 1954; Jewell et al., 2012).

The genus name *Aceria* was initially confused with *Eriophyes* in the literature following a proposal by Newkirk and Keifer (1971) to revise the type species designation for the latter, which was then corrected by the International Commission on Zoological Nomenclature (Lindquist, 1996). However, in relation to the eriophyoid bermudagrass mite, *Ac. cynodoniensis*, the use of *Eriophyes* instead of *Aceria* has persisted in some American publications, even quite recently (e.g. Williamson et al., 2013).

To date, six different *Aceria* species from *C. dactylon* have been described in the world literature, namely: *Aceria cynodoniensis* (Sayed, 1946), *Aceria neocynodoniensis* Keifer, 1960 (regarded as a junior synonym of *A. cynodoniensis*), *Aceria nilotica* (Abou-Awad and Nasr, 1983); *Aceria dactylonae* (Mohanasundaram, 1983), *Aceria distinctus* (Mitrofanov et al., 1988) and *Aceria cynodonis* (Wilson, 1959). The published morphological descriptions for each of these species are summarized in Table 1. Like *Ac. neocynodoniensis* (junior syn.), It is important to note that some of these other species may also eventually be found to be junior synonyms of *A. cynodoniensis*. However, this would require the subsequent collection and careful taxonomic assessment of additional actual specimens since the original type material is unlikely to be available for study. It is also possible that all of these species are valid. However, with the use of other diagnostic tools which include both such as molecular and morphological analysis would be useful in conjunction with morphological identification in this regard. Even eriophyoid “species” previously thought to be less host-specific are increasingly being shown to consist of a number of cryptic species (specialized races), each specific to a particular plant species (e.g. Skoracka and Dabert, 2010; Skoracka et al., 2012).

(Insert Table 1 near here)

Abacarus cynodonis. The identification of *Abacarus cynodonis* on *C. dactylon* is interesting, and is a new record for Australia. Although not frequently found (or at least identified) and only occurring in low numbers, it shows that this previously unrecorded species has a fairly broad distribution in Australia following its identification in a sample from NSW (Sydney) in 2009, Western Australia (Perth) and Queensland (Townsville) in 2011.

Little is known about the visual symptoms associated with *Ab. cynodonis*. Notes provided with the Townsville collection mention “yellowing of plants”, but both *Ac. cynodoniensis* and *D. australianus* also occur at that site and could well account for the shortening of plant nodes and patchy grass cover that were also noted with that collection. According to Abou-Awad and Nasr (1983) in their original description of this species from Egypt, *Ab. cynodonis* mites appear to be vagrants on the leaves preferring the upper surface of leaf blade causing curling of the leaves. Like most eriophyoid mites, it is probably a plant feeder but the damage symptoms, if significant, are yet to be clearly defined. Therefore, this species is not considered to be of current concern despite the fact that the genus *Abacarus* includes economic pests such as *Abacarus hystrix* (cereal rust mite). *Ab. hystrix* occurs in Australia and has a relatively wide host range on cereals and other grasses (including *C. dactylon*), though it may eventually prove to be a complex group of cryptic species targeting different host plant species (Skoracka and Kuczyński, 2006).

Abou-Awad and Nasr (1983) first described *Ab. cynodonis* from bermudagrass in the Sinai Peninsula, Egypt and specimens identified from Australia have been compared with their description in the literature. We note also that the original species name for *Ab. cynodonis* has subsequently been misspelt in the literature as *Abacarus cynodonsis* by Amrine and Stasny (1994) and followed by Wang et al. (2014). Smith Meyer (1989) also recorded this species as being from Africa, although the exact locality and host plant species was were not specified and so she may simply have recognized the initial collection described by Abou-Awad and Nasr (1983). More recently, *Ab. cynodonis* has been identified from Saudi Arabia (Wang et al., 2014) but not on its usual grass host, *C. dactylon*. Rather, it was reportedly found on *Sesuvium portulacastrum*, a coastal plant from the plant family Aizoaceae. Intriguingly, Wang et al. (2014) also reported *Ac. cynodoniensis* from Saudi Arabia for the first time on the same host plant. Given that eriophyoid mites are highly host specific, the finding of *Ab. cynodonis* and *Ac. cynodoniensis* on an unrelated host from a completely different plant family clearly warrants further investigation to validate this report.

2. Tenuipalpidae. The taxonomic history and prior records for *D. australianus* have been discussed in detail by Seeman et al. (2016b). Like *Ac. cynodoniensis*, its native range is likely North Africa and the Middle East, reflecting the native range of its host plant, even though it was first described from bermudagrass in Queensland by Womersley (1943). Prior to our study, *D. australianus* was thought to be found only in the state of Queensland (Smiley and Gerson, 1995), but this species has now been shown to occur Australia-wide on bermudagrass, from Mt Isa and

Charters Towers (QLD) to Broome (WA). Intriguingly, the historical records also include a collection reportedly made in Sydney (NSW) in 1939. *D. australianus* also occurs within its presumed native range and through to southern Africa, being found in Egypt (Sayed, 1938, 1946 – as *D. floridanus*; Wafa et al., 1968-69), Iran (Baharloo et al., 2006), Saudi Arabia (Alatawi et al., 2015 – as *D. riyadhensis*), South Africa (Meyer, 1979) and Zimbabwe (Goldsmid, 1962).

3. Tarsonemidae. Tarsonemid mites cover a wide range of feeding behaviour, but those on grasses are probably either fungivorous or phytophagous. While some tarsonemid mites appear not to damage the associated grass plants, the genus *Steneotarsonemus* is regarded as phytophagous. It is therefore significant that *Steneotarsonemus hippodromus* was found in most samples of kikuyugrass (76% post survey), especially those with green leaves showing no discoloration. To date, *S. hippodromus* has been found on no other turfgrass or other grass species. Even though the mite was has only just been described by Seeman et al. (2016b), it has been widespread in Australia and known to Australian acarologists since at least the mid-1960s, being present in Far North Queensland (Upper Barron) and western Sydney at that time (Allen, 1967; historic records). This mite may also have a global distribution, since kikuyugrass is native to east Africa. Significantly in this regard, *S. hippodromu*s was also recently discovered in California (Seeman et al., 2016b). Two other tarsonemid mites, *Steneotarsonemus kruseae* and *Tarsonemus scaurus* have also been recorded from kikuyugrass in Costa Rica (Ochoa et al., 1991, 1994; Lin and Zhang, 2002).

Although common in kikuyugrass, mite numbers (maximum of 85 in a sample) were in stark contrast to the tens of thousands of eriophyoid and tenuipalpid mites that infested bermudagrass. Mites were rare in grass with dead or dying plant growth, but were common in green grass, where small colonies established just under the sheath around the node. The plant tissue around these colonies was often discolored (yellowing of cells), but whether or not this probable feeding damage leads to the distorted growths we observed is unknown, and warrants further attention. In the rice panicle mite, *Steneotarsonemus spinki*, outbreaks result in up to 1,100 mites per tiller (Tseng, 1984) and cause substantial damage to rice. Nevertheless, even small populations of *S. spinki* may be associated with significant damage, depending on the growth stage of the plant (Jiang et al., 1994), although the effects of the mite are often difficult to separate from those of pathogens (Hummel et al., 2009).

4. Tetranychidae. Colonies of grass-webbing mites, namely *Oligonychus araneum* (Davis, 1968) and *Oligonychus digitatus* (Davis, 1966), are occasionally seen on a wide range of warm-season turf and other grasses. These two species often occur together in the same infestation (Gutierrez and Schicha, 1983). Such colonies are obvious even to a casual observer because of the distinctive protective webbing woven over the top of the mites. Only one grass-webbing mite infestation was recorded during the period of our study, though such infestations can be quite numerous in certain years when suitable conditions occur. The two *Oligonychus* species have only been recorded in Australia, with records of apparent and confirmed infestations going back around 80 years (Anon., 1936; Davis, 1968).

Visual Symptoms and diagnosis of mite infestations

In commercial practice, the diagnosis of a mite infestation is almost invariably based on the symptoms seen on the plant host. For this reason, we have provided detailed illustrated descriptions of symptoms seen on different turfgrass hosts and their association with the different groups of mites identified. With experience, the subtle differences in symptoms on bermudagrass give a reasonable guide as to which of the two major mite species, *Ac. cynodoniensis* or *D. australianus*, is likely to be involved (or, at least, which might be the more dominant species). However, not every rosetted or distorted growth on a plant will yield mites (as our results showed). Direct examination through dissection and/or laboratory extraction of plant material is the only reliable way for turf producers and managers to confirm the presence of mites and to determine the possible identity and/or mix of species involved in an infestation. Cheap portable microscope systems that attach to a computer through a USB port are now readily available, making direct examination a more feasible option which would allow the two main genera on bermudagrass, *Aceria* and *Dolichotetranychus*, to be distinguished.

Implications for Chemical Registration

The work reported here was aimed primarily at elucidating the taxonomy of the main turf mite species involved to facilitate the future registration of chemicals that are better targeted for their control. In addition, this study has also provided a platform on which future ecological and biological turf mite studies can be developed.

Worldwide, relatively few miticides are registered for turf use (Williamson et al., 2013). A recent search of the Australian Pesticides and Veterinary Medicines Authority’s (APVMA’s) Public Chemical Registration Information System (PUBCRIS) database showed seven products covering four different active ingredients (all adulticides) registered for mite control in turf – a situation that limits opportunities for rotation of chemical groups to minimize the inevitable risk of resistance developing longer term. Moreover, all of these current registrations are for control of the eriophyoid “couch mite”.

The effectiveness of different miticides, however, varies according to the group of mites targeted, and the chemicals currently registered for couch mite may not be equally effective on tenuipalpid and tarsonemid mites as shown in recent preliminary work by McMaugh and Loch (2015). Previous trial work leading to registration also appears to have been based on indirect observation of symptoms. In the future, data for registration should be, or should at the very least include sufficient data, based on direct observation of the mites concerned and should cover all of the major species that infest warm-season turfgrasses in Australia. For chemical registration purposes, identification of mites found in supporting trials should be done by a specialist acarologist.

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CAPTION FOR TABLE

Table 1. Comparative summary of published morphological data for six *Aceria* species from *Cynodon dactylon* as described in the world literature.

CAPTIONS FOR PLATES

Plate 1. *Aceria cynodoniensis* damage to *Cynodon* spp.: (a) and (c), infested swards showing ‘witches brooming’ (rosetting) of distorted growths in situ; (b) and (e), mites and eggs found under leaf sheath; (d) and (f), close-up views of witches brooms and distorted shoots.

Plate 2. *Dolichotetranychus australianus* damage to *Cynodon* spp.: (a), weak sward growth showing ‘pinetree-like’ growths without rosetting; (b), mites and eggs found under a leaf sheath; (c), death of sward due to severe mite infestation; (d), close-up view of pinetree like growths; (e), female *Dolichotetranychus australianus* mite; (f), elongated pinetree-like growth (8-cm long) found in an old mite infestation.

Plate 3. *Steneotarsonemus hippodromus* damage to P*ennisetum clandestinum*: (a) and (d), distorted growth in short-cut turf; (b), female mite and eggs found under a leaf sheath; (c) and (f), distorted growth in ungrazed pasture-length grass; (e), electron micrograph of female *Steneotarsonemus hippodromus* mite.

Plate 4. Australian distribution maps based on locations for current and historic samples of (a) *Aceria cynodoniensis*, (b) *Dolichotetranychus australianus*, (c) *Abacarus cynodonis*, and (d) *Steneotarsonemus hippodromus*.

Aceria couch mite. Products trialled only against this eriophyid species risk doing half the job of couch mite control

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Couch mite... which mite?

After many years delving into one of the most interesting yet destructive of turfgrass pests, Dr Don Loch provides a definitive update on local research which clearly demonstrates there is more than one species of couch mite that Australian turfgrass managers need to be aware of and to be able to control effectively.

Horticulture Innovation Australia

Australian research into couch mite over the past five years has gone a long way towards unravelling what is clearly a complex area with major implications both for turf producers and for turf managers.

Funding from Horticulture Australia Limited (now Horticulture Innovation Australia) has been instrumental in facilitating this ground-breaking work, starting with an Australia-wide survey of phytophagous (plant feeding) mites on warm-season turfgrasses in 2010/11 (TU10002). The limited time and the large number of samples (117) processed in this survey meant that the mites recovered were only identified provisionally at genus level.

A new Horticulture Innovation Australia project (TU13021), with matching financial support from Racing Queensland and the Australian Racing Managers Association, has now enabled our research team to undertake the task of identifying the mites groups of interest down to species.

Through our research over the past five years, we now have an extensive database on the distribution of mites on different turfgrasses in Australia. Sampling continued after our 2010/11 survey and with additional collections since then we now have data on a further 200 samples. These also include kikuyu grass (*Pennisetum clandestinum*) and zoysia grasses (*Zoysia* spp.). In this paper, however, I will only be dealing with the couch grass mite complex.

COUCH MITE SPECIES

For green couch (*Cynodon dactylon* and its hybrids with *C. transvaalensis*), the number of samples with phytophagous mites in our initial survey was almost evenly divided between *Dolichotetranychus* (Tenuipalpidae) and *Aceria* (Eriophyidae) species. A similar trend (possibly weighted slightly in favour of *Dolichotetranychus*) has continued in our subsequent sampling, with the complication of mixed tenuipalpid-eriophyid populations found at eight sites.

Our survey also found a second eriophyid mite, an *Abacarus* species, in one sample of green couch from Perth. A recent search of Australian reference collections has located two more samples of what appears to be the same *Abacarus* species in green couch, one from Sydney and the other from Townsville. It is not yet possible to determine the impact and significance of this hitherto unknown and unsuspected eriophyid species which appears to be distributed Australia-wide although not frequently collected or identified.

SYMPTOMS

The visual symptoms (i.e.: the distorted growths, or galls) caused by infestations of the two main couch mites are subtly different, but relatively easy to distinguish with experience. Over the past two years, for example, my assessments based on field symptoms have proven almost 100 per cent correct when these samples have subsequently been assessed by acarologists in our research team.

Witch's brooms (rosetted growths at stolon nodes) and poor stolon root development are typical of *Aceria* infestations, which are often concentrated more along edges rather than being spread across an area. At the same time, individual growths within an *Aceria* witch's broom become shortened, thickened and flattened laterally (and with leaves greatly reduced in length) to give a 'pinetree' effect.

The *Dolichotetranychus* species, on the other hand, produces a characteristic thinning and weakening of the stand, often concentrated in patches, but frequently also spread across an infested area. There is markedly less proliferation of distorted growths at stolon nodes (i.e.: no strong witch's brooming).

These pinetree-like growths are slightly more thickened and rounded with even shorter leaves than for *Aceria*. *Dolichotetranychus* can also be found persisting in some quite old, half-dead, elongated pinetree-like growths (up to 8cm or more long), though not as prevalent as in younger growths. In the case of mixed *Aceria-Dolichotetranychus* populations, the external symptoms tend to follow the dominant species.

Aceria symptoms (left) and *Dolichotetranychus* symptoms (below). Note the fatter, more rounded pinetree-like growths and the absence of witch's brooming in the latter case

IMPACT OF COUCH MITE INFESTATIONS

Mites distort the new growths on green couch and reduce the rate of growth. In three replicated pot experiments with a *Dolichotetranychus*-infested treatment, I measured reductions in dry matter production of 75, 70 and 50 per cent through mite infestation.

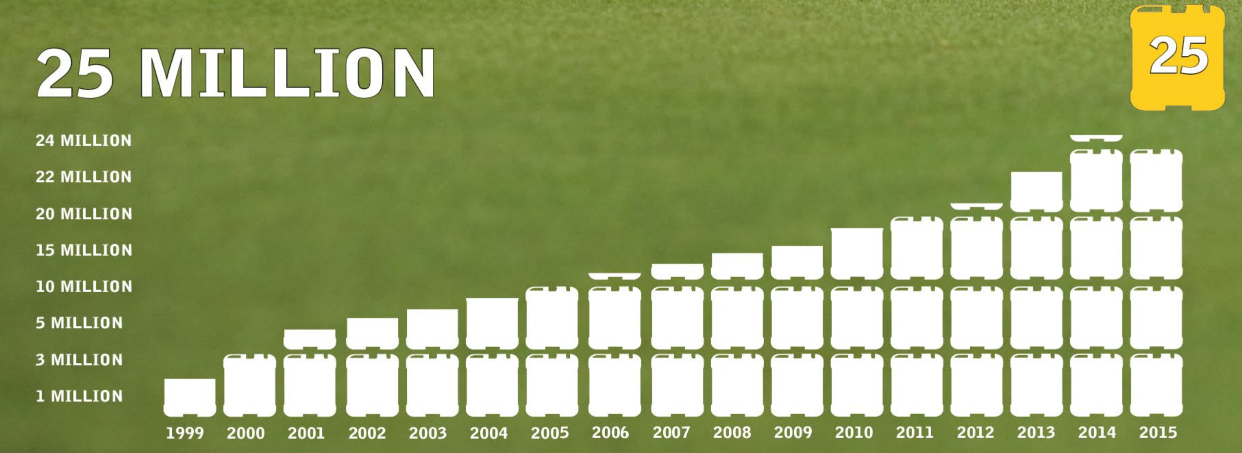
Anecdotally, the *Dolichotetranychus* couch mite can be more damaging than the eriophyid *Aceria* mite, as shown in the photograph (right) of a Brisbane suburban sportsfield where all of the green cover was wiped out despite good soil moisture.

Total devastation of a green couch sportsfield caused by *Dolichotetranychus*

Additionally, stolon, root and rhizome development are weaker on mite-affected turf, with the result that production turf fails to knit and bind together properly leading to longer production cycles and breakage of rolls at harvest, with losses of 30 per cent or more. Affected turf is also more easily water-stressed due to its poor root development.

Managers of established turf facilities face two major issues in the event of a mite outbreak:

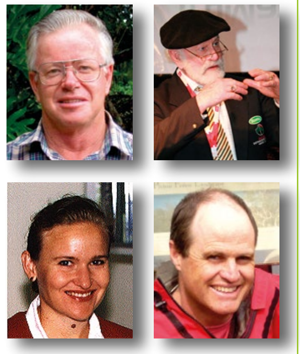
▶



Dolichotetranychus – the forgotten couch mite

- The reduced use that is possible as a result of the much poorer wear resistance and the extremely slow recovery from wear of the mite-affected turf; and
- The poor quality and uneven nature of the turf surface through distortion and thinning.

Indirectly, costly mistakes can be made where a mite infestation is not recognised. During our survey, some parks managers were investing in ineffective water crystals to overcome the perceived drought susceptibility of their turf, while overlooking the mite damage actually causing this effect.



The research team (clockwise from top left) Don Loch, Peter McMaugh, Owen Seeman and Danuta Knihinicki

HISTORY AND ORIGIN OF COUCH MITES IN AUSTRALIA

Records of the two common couch mite species date back more than 70 years. The tenuipalpid *Dolichotetranychus australianus* was described from samples collected in 1943 from an infested green couch bowls green in Queensland. Conventional wisdom seemed to be that *Dolichotetranychus* mites were confined to Queensland until our survey proved otherwise. Although described from an Australian collection, it appears more likely that *D. australianus* originated elsewhere, probably in Africa where widely separated infestations on bermudagrass were recorded much earlier from Egypt to South Africa.

Witch's brooming symptoms on green couch caused by an *Aceria* species were first reported in 1934 in Western Australia, with the next recorded occurrence (as *Aceria cynodoniensis*) coming from NSW in 1967. Most eriophyid mites are highly host-specific, so the apparently exclusive association of the eriophyid couch mite with *Cynodon dactylon* and its hybrids is not unexpected.

Dolichotetranychus causes pinetree-like growths that are slightly more thickened and rounded with even shorter leaves than *Aceria*

Recent suggestions in American literature that *A. cynodoniensis* is probably native to Australia, but without any supporting evidence, therefore do not fit well with the presumed centre of origin for *C. dactylon* being located in the Middle East and its widespread distribution throughout Africa, nor with the fact that most (if not all) *Cynodon* genotypes in Australia are derived from imported material post-1788. Earlier US acarologists in the 1960s believed that *Aceria cynodoniensis* is native to Africa; and until there is definitive proof to the contrary, this remains the most likely scenario.

RESISTANCE TO COUCH MITES

In our experience, there are no green couch cultivars or genotypes that could be confidently described as completely resistant to couch mite. Rather, there seem to be differences among cultivars in terms of their susceptibility to, and the level of damage from, mites.

Even more intriguing, some varieties and even lines of breeding appear to be more prone to infestations by one or other of the two couch mite species. Common sense would dictate that the more susceptible varieties be phased out commercially.

Over the past five decades, numerous trials have been conducted across a range of *Cynodon* varieties in the US aimed at determining their relative resistance to *A. cynodoniensis* by assessing the spread of mites between pots in the glasshouse. The results, however, have been inconsistent from year to year and from trial to trial.

The results of my own attempts to establish mites in mite-free pots by "seeding" with infested material or facilitating spread through close proximity with infested pots are best described as unreliable. Until we have a better understanding of the underlying factors that encourage couch mites to spread and establish new colonies, information from such trials must always be tempered with caution.

CONTROL OF COUCH MITES

The mites (Class: Acari) are a large and diverse group, second only to the insects in number of species. Not surprisingly, chemical control cannot be approached as a case of one size fits all – an effective miticide on one group may not work at all with another group of mites. Anecdotally, *Dolichotetranychus* couch mites are the more difficult to control and we have examples of infestations that have persisted for more than 10 years in spite of all control measures tried.

There are currently seven products (based on four active ingredients) registered for 'couch mite' control, only three of which actually specify that this refers to the eriophyid *Aceria cynodoniensis*. In preliminary screening trials on *Dolichotetranychus* in green couch and tarsonemid mites in kikuyu in another HAL-funded project (TU10004), two of the currently registered actives proved ineffective on both mites, as was an oil-based product promoted as an 'organic' solution.

Our recommendation is that all future registrations for couch mite control should cover both mite groups and that identification of the target mite in each experiment be confirmed by a specialist acarologist.

MYTHS AND MISCONCEPTIONS

Some of the naïve, ignorant and just plain stupid comments that can emanate from self-appointed experts looking to sell product never cease to amaze and amuse us. A good example of the level of misinformation possible is the furphy that mites in turf have come from casuarinas or other trees nearby.

The eriophyid couch mite occurs exclusively on green couch. And while the host range of the *Dolichotetranychus* couch mite has not been definitively determined – it has been found on at least one other turfgrass (though possibly migratory rather than being settled) – it is most closely associated with green couch. So any mites that might be found in nearby trees will be some of the many thousands of other phytophagous mite species, each with different host ranges that do not include green couch or any other turf grasses.

DISSEMINATION OF INFORMATION

A detailed final report on our initial survey has been available from HAL/HIA for the past four years. A wall chart describing both couch mite species was distributed to Turf Producers Australia members and handed out free at the 2012 Australian Turfgrass Conference where I also gave a detailed presentation and written paper on our work.

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In our 2011 report, we highlighted the poor level of information available on turf mites through commercial websites in Australia – selective and Amero-centric at best, misleading at worst. Yet virtually nothing has changed since then. Is anyone out there in commercial-land actually listening and reading? Are our so-called commercial researchers keeping up with the literature and new developments in their own backyard, which is fundamental to good science?

My message to the commercial turf industry about couch mite in Australia can be summed up in a well-known quote from Shakespeare's *Hamlet* – "There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy."

Typical *Aceria* witch's brooming (top) and a large, long-established *Dolichotetranychus* gall (bottom)

Couch Mite ... Which Mite

Dr Don Loch

Honorary Senior Fellow (University of Queensland) & Principal Scientist (GeneGro Pty Ltd)

2014/15 was a bad, bad year for mites on couch grass.

Unfortunately, commercial wisdom about couch mites (together with associated control measures) remains focussed solely on the eriophyid mite species, **Aceria cynodoniensis**, based on old US records. This outdated and simplistic approach runs contrary to recent Australian research, which has clearly demonstrated that there is more than one species of couch mite that Australian turfgrass managers need to be aware of and to be able to control effectively.

The aim of the present article is to set the record straight in relation to our current knowledge about couch mites in Australia.

Recent Research on Turfgrass Mites in Australia

Australian research over the past 6 years has gone a long way towards unravelling what is clearly a complex area with major implications, both for turf producers and for turf managers.

Funding from Horticulture Australia Limited (HAL – now Horticulture Innovation Australia) has been instrumental in facilitating this ground-breaking work, starting with an Australia-wide survey of phytophagous (plant feeding) mites on warm-season turfgrasses in 2010/11 (TU10002). The limited time and the large number of samples (117) processed in our survey meant that the mites recovered were only identified provisionally at genus level. A new HAL project (TU13021) with matching financial support from Racing Queensland and the Australian Racing Managers Association has now enabled our research team to undertake the task of identifying the mites groups of interest down to species.

Through our research over the past 6 years, we now have an extensive database on the distribution of mites on different turfgrasses in Australia. Sampling continued after our 2010/11 survey. And with additional collections since then, we now have data on a further 200 samples. These also include kikuyu grass (Pennisetum clandestinum) and zoysia grasses (Zoysia spp.). In this article, however, I will only be dealing with the couch mite complex.

Couch Mite Species

For green couch (Cynodon dactylon and its hybrids with C. transvaalensis), the number of samples with phytophagous mites in our initial survey was almost evenly divided between Dolichotetranychus (Tenuipalpidae) and Aceria (Eriophyidae) species. A similar trend (possibly weighted slightly in favour of Dolichotetranychus) has continued in our subsequent sampling, with the additional complication of mixed tenuipalpid-eriophyoid populations found at 16 sites.

Our survey also found a second eriophyid mite, an Abacarus species, in one sample of green couch from Perth. A recent search of Australian reference collections has located two more samples of what appears to be the same Abacarus species in green couch, one from Sydney and the other from Townsville. It is not yet possible to determine the impact and significance of this hitherto unknown and unsuspected eriophyid species, which appears to be distributed Australia-wide although not frequently collected or identified.

Symptoms. The visual symptoms (i.e. the distorted growths, or galls) caused by infestations of the two main couch mites are subtly different, but relatively easy to distinguish with experience. Over the past 2 years, for example, my assessments based on field symptoms have proven almost 100% correct when these samples have subsequently been assessed by acarologists in our research team.

Witch's brooms (rosetted growths at stolon nodes) and poor stolon root development are typical of Aceria infestations, which are often concentrated more along edges rather than being spread across an area. At the

Aceria symptoms

Aceria symptoms, "Witches broom"

same time, individual growths within an Aceria witch's broom become shortened, thickened and flattened laterally (and with leaves greatly reduced in length) to give a 'pinetree' effect The Dolichotetranychus species, on the other hand, produces a characteristic thinning and weakening of the stand, often concentrated in patches, but frequently also spread across an infested area. There is markedly less proliferation of distorted growths at stolon nodes (i.e. no strong witch's brooming). These pinetree-like growths are slightly more thickened and rounded with even shorter leaves than for Aceria. Dolichotetranychus can also be found persisting in some quite old, even half-dead, elongated pinetree-like growths (up to 8 cm or more long), though

Dolichotetranychus, "Pine tree growth"

Dolichotetranychus symptoms)

In the case of mixed Aceria-Dolichotetranychus populations, the external symptoms tend to follow the dominant species.

Impact of Couch Mite Infestations. Mites distort the new growths on green couch and reduce the rate of growth. In three replicated pot experiments with a Dolichotetranychus-infested treatment, I measured reductions in dry matter production of 75, 70 and 50% through mite infestation. Anecdotally, the Dolichotetranychus couch mite can be more damaging than the eriophyid Aceria mite, as shown in the accompanying photograph of a Brisbane suburban sportsfield where all of the green cover was wiped out despite having good soil moisture.

Additionally, stolon, root and rhizome development are weaker on mite-affected turf, with the result that production turf fails to knit and bind together properly leading to longer production cycles and breakage of rolls at harvest, with losses of 30% or more. Affected turf is also more easily water-stressed due to its poor root development.

Managers of established turf facilities face two major issues in the event of a mite outbreak:

1. The reduced use that is possible as a result of the much poorer wear resistance and the extremely slow recovery from wear of the mite-affected turf; and
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Indirectly, costly mistakes can be made where a mite infestation is not recognised. During our survey, for example, some parks managers were investing in ineffective water crystals to overcome the perceived drought susceptibility of their turf, while overlooking the mite damage that was actually causing this effect.

History and Origin of Couch Mites in Australia

Records of the two common couch mite species date back more than 70 years. The tenuipalpid Dolichotetranychus, australianus was described from samples collected in 1943 from an infested green couch bowls green in Queensland. Conventional wisdom seemed to be that Dolichotetranychus mites were confined to Queensland until our survey proved otherwise. Although described from an Australian collection, it appears more likely that D. australianus originated elsewhere, probably in Africa where widely separated infestations on bermudagrass were recorded much earlier from Egypt to South Africa.

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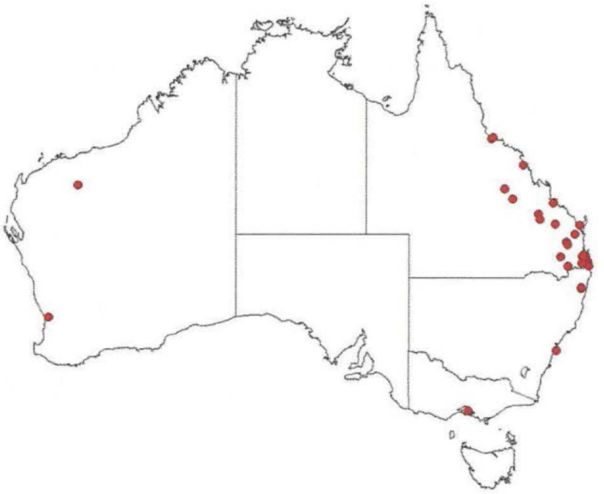
aceria distribution



dolichotetranychus distribution