Mite Damage - A Survey of four warm season turf grasses

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Turfgrass Scientific Services Pty Limited

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TU10002

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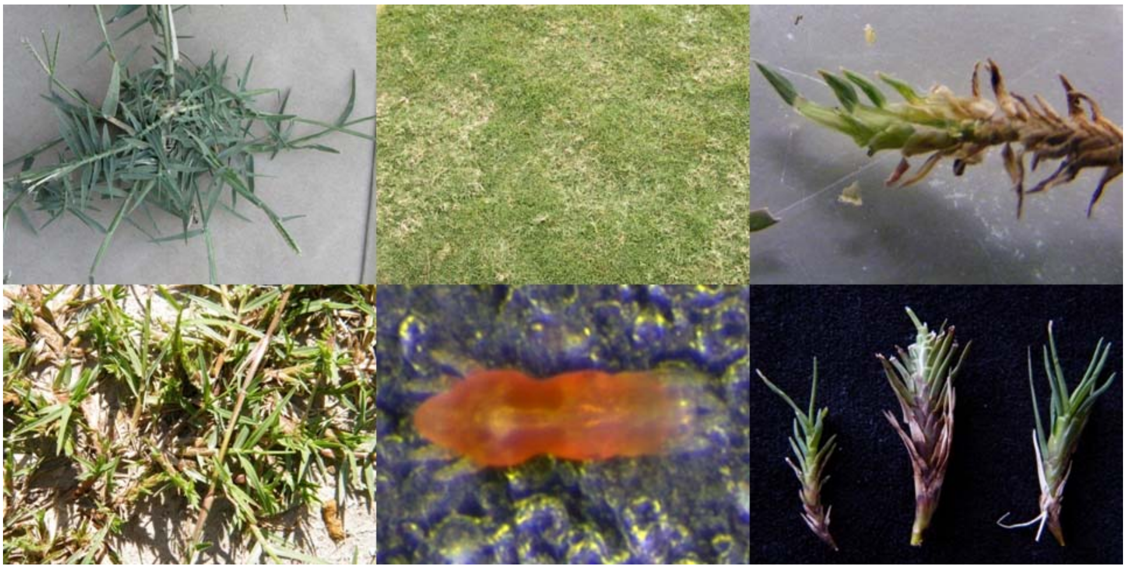
FINAL REPORT

TU10002 (20 May 2011)

Mite Damage:
A Survey of Four Warm-Season Turf Grasses



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Purpose of Report

This report presents the findings of a survey of several warm-season turf grasses which show symptoms of mite damage. It reports the geographic and botanical spread of samples taken, including the collection dates and locations. It provides diagnostic analysis of the mites found in these samples or notes their absence.

The report also includes a comprehensive literature review on the occurrence and biology of phytophagous (plant-feeding) mites across warm-season turfgrass species, particularly mites which appear to be more host-specific in terms of the range of grasses affected.

This report contains much new information about mites and their relationships with various turfgrasses. However, the findings and conclusions open more questions than they provide definitive answers, albeit at a higher level of information than before; and it is clear that to get a comprehensive total picture much more work will be required to build on the start made through this survey.

Acknowledgement

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Date: 20 May, 2011

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MEDIA SUMMARY

Mites cause significant loss of production on commercial turf farms and lower the quality of product sold to the turf customer. In other areas (notably recreational turf), mites cause major growth retardation at the time of recovery after wear.

Horticulture Australia Ltd Project No. TU10002 (Mite Damage: A survey of four warm-season turf grasses) had two major components. These were:

1. Collection of samples from various venues including production turf farms, playing fields, race tracks, golf courses and general public recreational area, Australia wide; and
2. Taxonomic identification by Ms Danuta Knihinicki (acarologist with NSW Primary Industries, Orange) of the mites found in the samples collected.

This project has enabled us for the first time to determine accurately the different groups of mites that are present in several different species and varieties of turfgrasses. The results have changed the previously assumed situation with regard to the mite species present, and have added at least two previously unsuspected mites to our information bank. The limited scope of this preliminary project has not enabled us to identify every mite collected down to species level. However, it sets the scene for improved life cycle studies and chemical control treatments, the second of which is the subject of two further HAL projects to be completed in late 2011.

TECHNICAL SUMMARY

HAL Project TU10002 entitled 'Mite Damage: A survey of four warm-season turf grasses' was initiated because of the lack of knowledge about turfgrass mites: which species of microscopic mite, if any, was causing damage and to which turfgrass species. There has long been an underlying assumption, based on overseas literature and some limited laboratory experience locally, that mites of the family Eriophyidae (ACARI) were the main causal organisms of the distorted growth symptoms frequently seen and attributed to mite damage. The scientific literature related to turfgrass mites in Australia is almost non-existent, and commercial 'information' is based, usually erroneously, on USA experience with eriophyoid mites. The only recent reference that has attributed couchgrass mite damage to a tenuipalpid mite, *Dolichotetranychus australianus*, was made in 'What Garden Pest or Disease is That?' by Judy McMaugh (1986). This relates back to Womersley's 1940s original identification and description of that mite species from green couch material from south-east Queensland.

Based on long experience and observation, mites can cause serious commercial losses of turf in commercial production where the distorted growth prevents adequate cross runner growth to give sufficient sod strength during harvest, even after a longer growing period. Elsewhere, mite infestation is associated with very slow recovery of turf on playing fields after heavy wear. Lawns also show distorted growth due to mites, especially under dry conditions. Across Australia, the damaging effects of mites on turfgrasses have been exacerbated by the recent prolonged drought.

In an Australia-wide survey across 5 states and one territory during the 2010/11 growing season, 119 samples were taken from turf production areas (40%), parks (30%), sporting venues (13%), research facilities (13%) and naturalised areas and submitted to Primary Industries NSW's laboratory in Orange for extraction and mite identification. The grasses sampled included green couch (44 samples), kikuyu grass (26 samples), buffalo grass (16 samples), three different *Zoysia* species (20 samples), blue couch (3 samples), seashore paspalum (4 samples), marine couch (2 samples) and one sample from an associated weed grass species. The actual numbers of samples from each grass varied from state to state, depending on the mix of turfgrasses actually grown. Because identification down to species level is a painstaking and time-consuming process, mites extracted from the samples collected were identified at this stage down to genus only for this base-line study. Differences in the associated symptoms found provide a guide to the type of mite present.

Based on frequency of occurrence, the survey showed that tenuipalpid mites belonging to the genus *Dolichotetranychus* were as important, if not more important, than eriophyoid mites on Australian turfgrasses. They were found to affect green couch, kikuyu, zoysia and blue couch. *Dolichotetranychus* mites are slow-moving and usually form infestations as concentrated patches; they appear to be less restricted by cold weather than eriophyoid mites; and they also seem to be harder to control, possibly because of difficulties in getting miticide under the tight leaf sheaths in the distorted galls produced.

Eriophyoid mites of the genus *Aceria* were extracted from green couch and the three *Zoysia* species. Typically, eriophyoid mites are highly host-specific. The *Aceria* species affecting green couch is probably *A. cynodoniensis*, which is the main species affecting the same grass in the USA. However, symptoms consistent with a second *Aceria* species found on green couch in the USA have not been seen in Australia. Similarly, the zoysias in Australia appear to be affected by an unknown *Aceria* species different from that found in the USA.

INTRODUCTION

Mites have been identified as a problem in warm-season turfgrasses for over 70 years. The only mite discussed in turf literature in Australia or taught in educational courses at TAFE and other institutions has been 'couch' mite. When this mite has been discussed in Australia, it has almost universally been assumed that the species in question was *Aceria cynodoniensis (= A. neocynodonis)* which is the same species to which the damage in *Cynodon dactylon* (bermudagrass, green couch grass) and hybrid *C. dactylon X transvaalensis* has been mainly attributed in the USA.

The most common form of damage has been described as 'witches' broom', and is the result of distorted growth in the terminal shoots of green couch caused by mites living in the leaf sheaths of the affected grass. Distortion is produced by internode shortening and shortening of the leaves. The exact mechanism by which this distortion is controlled is not known.

Because eriophyoid mites are extremely small and almost colourless, they are very difficult to see during dissection of plant material. Whilst working at the Australian Turfgrass Research Institute during the 1960s, the principal investigator often observed eriophyoid mites in couch grass samples which had been stained with lactophenol cotton blue dye for general pathological examination. He generally assumed these mites were an *Aceria* sp., but because of the lack of resources was unable to take identification further.

In 1986, Judy McMaugh published the book 'What Garden Pest or Disease Is That?' with Lansdowne Press (McMaugh 1986). Under the entry for 'couchgrass mite' (p. 151), the pest is identified as *Dolichotetranychus australianus*. This attribution obviously came from a reference to a paper by Womersley, a South Australian acarologist, working at the South Australian Museum in the 1940s (see Review of Scientific Literature).

This very limited knowledge base, coupled with the principal investigator's experience of over 30 years as a turf producer, and 45 years as a turf consultant convinced him that 'mites' where a hugely limiting constraint on efficient economic turf production, as well as recovery of turf after wear in public recreation areas and domestic lawns.

The generic description of mite damage as 'witch's broom' also clearly did not fit every case of growth distortion that has been seen in the field. During a visit to Chile in 2009 to attend the International Turfgrass Society Research conference on a HAL-funded Study Tour (TU08044), our Australian group observed extreme growth distortion in *Pennisetum clandestinum* (kikuyu grass), which fitted all the symptoms of mite damage but was much worse than the levels of damage normally seen in Australia.

Some of the symptoms of mite damage observed in commercial row plantings of both green couch and kikuyu include looping of runners into aerial positions without attachment to the soil. A similar phenomenon is also typical of some *Stenotaphrum secundatum* (buffalo grass) cultivars in mature swards where it is graphically described as 'porpoising'. Distorted terminal growth, particularly in turf regrowth after harvest, leads to many small clumped plants with poor lateral runner extension and a subsequent lack of turf strength. At harvest time, this results in the cut rolls breaking up or tearing on the harvest conveyer and, hence, the loss of product (Plate 1). Losses in this way can be as high as 30%.

Plate 1. Broken rolls on a commercial turf farm showing a high percentage loss during harvest.

While these consequences of ‘mite’ infestation are well known, it was clear that no one really knew exactly which ‘mites’ and how many different ‘mites’ that Australian turf producers and managers were dealing with. Without knowing which mites are attacking which turfgrasses, effective control measures cannot be devised. Through the results of the survey presented in this report, we have taken the first definitive steps towards unravelling what is clearly a complex area with major implications for the Australian turf industry.

REVIEW OF SCIENTIFIC LITERATURE

Introduction

Mites (Acari or Acarina) are second only to the insects in terms of their species diversity. They are also the most diverse and abundant of the various Arachnid groups (Walter *et al.* 1996). The number of described mite species is increasing: about 55,000 in Walter (2006) compared with a total of 45,000 given by Walter *et al.* (1996) a decade earlier. However, this is still only a small fraction (perhaps around 5%) of the total number of mite species in the world, estimated to be >1,000,000 in all. Despite their abundance, mites tend to be a case of 'out of sight, out of mind' in terms of public awareness because they are tiny (mostly less than 1 mm in length as adults, with many less than 0.25 mm) and are rarely seen despite the more obvious damage that some species cause.

Almost all arachnids are predators (Walter 2006; Halliday 2008). The mites are the only arachnid group to have diversified beyond the predatory habit on a large scale and into an extremely wide range of niches. Many mites remain predatory, but there are also many thousands of species of plant feeders, fungivores, saprophytes, pollen and nectar feeders, microbial filter feeders, and internal and external parasites on a wide range of vertebrates and invertebrates. Some have a complex life cycle, in which parasitism and predation occur at different life stages within a species, while others are omnivorous.

Mites are ubiquitous (Walter 2006; Halliday 2008). They have successfully colonized nearly every known terrestrial, marine, and fresh water habitat including polar and alpine extremes, tropical lowlands and desert barrens, surface and mineral soils to depths of 10 meters, cold and thermal surface springs and subterranean waters with temperatures as high as 50°C, all types of streams, ponds and lakes, and sea waters of continental shelves and deep sea trenches to depths of 5,000 meters. Mites occur in soil and decomposing organic matter, in fresh water and sea water, high in the air, deep in the oceans, on and in the bodies of other animals, and on plants of all kinds. Their ecological diversity has been accompanied by a great range of morphological diversity, reinforced by their small body size enabling them to occupy minute spaces not available to larger animals.

Many mites have complex symbiotic associations with the larger organisms on which they live. Plants, including crops and the canopies of tropical rainforests, are inhabited by myriads of mite species feeding on mosses, ferns, leaves, stems, flowers, fruit, lichens, microbes, other arthropods and each other (Walter *et al.* 1996). Insects, especially those that build nests, live in semipermanent habitats like decaying wood, or use more ephemeral habitats like bracket fungi and dung, are hosts to a cornucopia of mite commensals, parasites and mutualists. As an example, Walter *et al.* (1996) state that a one square metre area of mixed temperate hardwood or boreal coniferous litter may have over one million mites representing some 200 species in at least 50 families. Within this complex matrix of decomposing plant matter, mites help to regulate microbial processes directly by feeding on detritus and microbes, and indirectly by predation on other microfauna.

The Acari includes a host of plant parasites (e.g. spider mites) that can devastate crops by their feeding or by transmitting plant pathogens, while others are potentially useful as biocontrol agents of weeds and other pests (Walter *et al.* 1996; Walter 2006). Domestic and wild animals, birds, reptiles and some amphibians can be infested by an often diverse range of parasitic mites, including some that cause debilitating disease and deformity. Even other arthropods are not immune, as the worldwide spread of the parasitic varroa mite on honeybees demonstrates. None of these mites exceed 1 cm in length, and most grow to less than 1 mm, yet they frequently have a major impact on their hosts.

What is a Mite?

Mites are not insects (class Insecta), although frequently studied along with insects by entomologists for the very practical reason that both arthropod groups include numerous pests of our cultivated plants and crops (Halliday 2008). Mites, together with the ticks, in the Sub-Class Acari form the largest and most diverse group within the class Arachnida, which also includes spiders, harvestmen, scorpions, whip scorpions and pseudoscorpions along with some other minor taxonomic groups (e.g. Jeppson *et al.* 1975; Walter *et al.* 1996; Walter and Proctor 1999). Together, mites and insects are the most diverse and numerous in terms of the species within the phylum Arthropoda, which includes animals with exoskeletons and articulated legs (Walter *et al.* 1996; Bruin *et al.* 1999).

Two of the defining structural features of the class Arachnida are their chelicerate mouthparts – basically, forcep-like feeding organs – and the complete lack of antennae (Jeppson et al. 1975); mandibles and maxillae (the typical mouthparts present in other arthropods) are also absent (Walter and Proctor 1999). Apart from their very small size, the Acari are distinguished from other arachnids by their absence of body segmentation, and by their fundamentally different body organisation (Walter 2006; Halliday 2008; see also Plate 2). Instead of the division of the body into cephalothorax (or prosoma) and abdomen as in other arachnids, the mouthparts and associated sensory structures form a discrete anterior structure known as the capitulum (or gnathosoma). Behind this, the remaining anatomical structures, including leg bases, central nervous system, and reproductive and digestive systems, are fused into a single unsegmented body called the idiosoma (equivalent to the posterior opisthosoma and part of the prosoma in other arachnids). Walter *et al.* (1996) make the point that many of the other characters sometimes used to define mites are present in various of the other Arachnid groups, and that mites in some respects are most easily recognisable in terms of what they are not - other arachnids - rather than by a more detailed set of discrete Acarine characteristics.

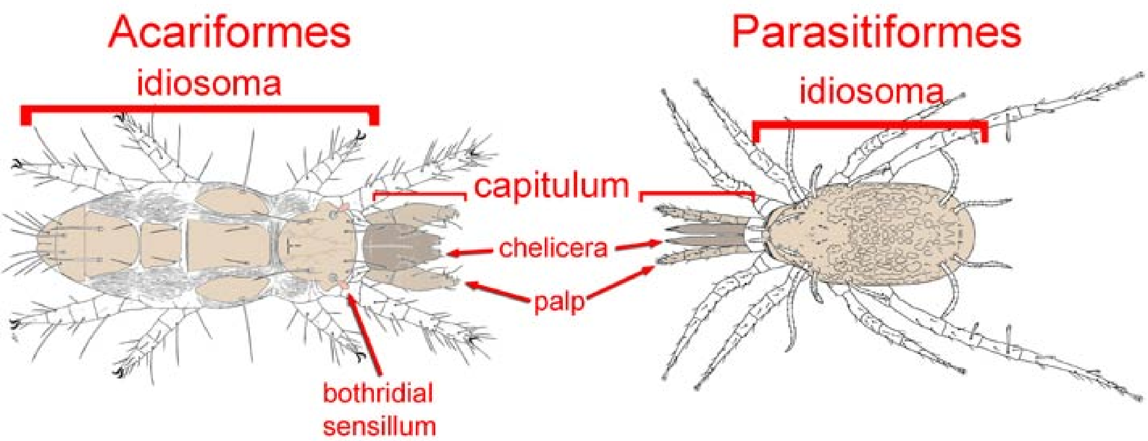

Plate 2. Generalised diagrams of body structure for mites from the superorders Acariformes and Parasitiformes (drawing from Walter 2006).

Mites are among the oldest of all terrestrial animals. Despite their small size and delicate structure limiting the amount of fossil remains (Jeppson *et al.* 1975), fossils of mites have been found dating back to early Devonian period nearly 400 million years ago (e.g. Norton *et al.* 1988, Kethley *et al.* 1989). The major evolutionary lineages are reflected in the two (or three) currently recognised superorders: Acariformes and Parasitiformes with (Walters *et al*. 1996) or without Opilioacariformes (Walter 2006; Halliday 2008; Krantz and Walter 2009).

Mites Recorded as Feeding on Warm-Season Turfgrasses

Across the world, phytophagous (plant-feeding) mites from 4 different Acari families have been reported on warm-season turfgrasses. *Cynodon dactylon* is represented as a host plant with all 4 families, although many of the mite species concerned have not been recorded in Australia.

Tetranychidae

Tetranychid mites are plant feeders of considerable economic importance (Baker and Pritchard 1960). Most species feed on leaves, damaging the surface with their chelicerate stylets. Halliday (1999) listed 54 tetranychid species compared with 1189 species worldwide (Bolland *et al.* 1998). While some tetranychid species are associated with one or a few host species, many such as the grass-webbing mites are much less host-specific and affect a wide range of plant species.

Of the 9 *Oligonychus* species recorded in Australia (cf. 192 species worldwide – Bolland *et al.* 1998), the 2 grass-webbing mites *O. araneum* and *O. digitatus* (described by Davis 1966, 1968) infest the leaf surfaces of a range of pasture and turf grasses (including *Cynodon dactylon, Digitaria didactyla, Pennisetum clandestinum* and *Stenotaphrum secundatum*) under suitable conditions. These two mite species often occur together in the same infestation (Gutierrez and Schicha 1983), which is obvious even to a casual observer because of the distinctive protective webbing woven over the top of the colony (Plate 3). Davis (1966) gives the collector's description as follows:

> *"...mites numerous in a ring-shaped infestation in the lawn, the grass in the outer part of the ring yellowed, that in the centre brown and dried out."*

Plate 3. Infestation of grass-webbing mites at Cleveland (Queensland), showing webbed colony (*left*) and close-up of webbing (*right*). (Photographs: D.S. Loch).

Bolland *et al*. (1998) list records of a number of other tetranychid mites collected from turfgrasses (Table 1). Some of these, particularly the more obscure species, have been collected from only one or a few host species, but this may be due to inadequate exploration and records rather than an indication of host specificity *per se*.

Wolfenbarger (1953) described 2 species of mites collected from *Stenotaphrum secundatum* and identified by E.A. McGregor. One species was identified as *Paratetranychus stickneyi*, later transferred to *Oligonychus stickneyi* by Pritchard and Baker (1955). The other was a new species, possibly a new genus, but close to *Monoceronychus*. Pritchard and Baker (1955) described *Monoceronychus mcgregori* on *S. secundatum* based on specimens collected by D.O. Wolfenbarger from Miami Shores, Florida on 5 May 1952 (very likely the same source). This species was later transferred into the genus *Neopetrobia* by Smith Meyer (1987) as listed in Table 1. Wolfenbarger (1953) described the symptoms of mite infestation on *S. secundatum* as follows:

> *"Symptoms of mite infestations on grass are similar to those of mite infestations on other plants. Blotching and stippling of the infested leaves result from mite feeding. In advanced stages of infestations the blotched areas may become brown and finally die. Browned and dead stolons and dead areas are common in heavily infested grass."*

Table 1. World records of tetranychid mite species collected from warm-season turfgrasses (from Bolland *et al.* 1998).

Mite Species	Turfgrass Host(s)	Alternate Hosts	Distribution	Other References
Bryobia meyerae	*Cynodon dactylon*	1	Egypt	Zaher *et al*. (1982)
Bryobia neopraetiosa	*Cynodon dactylon, Pennisetum clandestinum*	>30	South Africa, Zimbabwe	Smith Meyer (1974)
Bryobia praetiosa	*Cynodon dactylon, Pennisetum clandestinum*	>250	Worldwide including Australia	
Bryobia watersi	*Cynodon dactylon*	>5	Europe, New Zealand	
Bryobia inflata	*Cynodon dactylon*	Poaceae	Namibia, South Africa	Smith Meyer (1974)
Eotetranychus candanai	*Zoysia japonica*	9	Cambodia, Philippines, Taiwan, Thailand	
Eutranychus pyri	*Cynodon dactylon*	5	Egypt	
Monoceronychus aechmetes	*Cynodon dactylon, Distichlis stricta, Distichlis* sp.	3	USA	Pritchard and Baker (1955)
Monoceronychus californicus	*Cynodon dactylon, Distichlis spicata, Distichlis stricta*	6	USA, Mexico	McGregor (1945)
Monoceronychus scolus	*Cynodon dactylon*	>9	USA	Pritchard and Baker (1955)
Monoceronychus sticticus	*Cynodon dactylon*	>2	South Africa	Smith Meyer (1974)
Neopetrobia summersi	*Cynodon dactylon*	0	Egypt	Zaher *et al*. (1982)
Oligonychus afrasiaticus	*Cynodon dactylon*	5	North Africa, Middle East, Mexico	
Oligonychus amnicolus	*Cynodon dactylon*	1	South Africa, Zimbabwe	Smith Meyer (1974)
Oligonychus araneum	*Cynodon dactylon, Digitaria didactyla, Pennisetum clandestinum, Stenotaphrum secundatum*	Poaceae	Australia	Davis (1968)

Mite Species	Turfgrass Host(s)	Alternate Hosts	Distribution	Other References
Oligonychus dactyloni	*Cynodon dactylon*	0	Yemen	Smiley and Baker (1995)
Oligonychus digitatus	*Cynodon dactylon, Digitaria didactyla, Pennisetum clandestinum, Stenotaphrum secundatum*	Poaceae	Australia	Davis (1966)
Oligonychus duncombei	*Cynodon dactylon*	0	Zimbabwe	Smith Meyer (1974)
Oligonychus gramineus	*Stenotaphrum secundatum*	7	USA, French Polynesia, New Caledonia, Vanuatu	McGregor (1950)
Oligonychus indicus	*Cynodon dactylon*	20	China, India, Pakistan	
Oligonychus licinus	*Stenotaphrum dimidiatum*	7	Cameroon, Madagascar, Nigeria, Senegal, Zaire	Baker and Pritchard (1960)
Oligonychus oryzae	*Cynodon dactylon*	3	India, Thailand	
Oligonychus pratensis	*Cynodon dactylon, Digitaria diversinervis*	68	Asia, USA, Central America, Colombia, Hawaii, North Africa, Madagascar	
Oligonychus sayedi	*Cynodon dactylon*	0	Egypt	Zaher *et al*. (1982)
Oligonychus stickneyi	*Cynodon dactylon, Digitaria* sp., *Sporobolus* sp., *Stenotaphrum secundatum*	22	USA, Hawaii, Central America	McGregor (1950); Wolfenbarger (1953); Pritchard and Baker (1955)
Oligonychus waltersi	*Pennisetum clandestinum*	0	South Africa	Smith Meyer (1987)
Neopetrobia mcgregori	*Stenotaphrum secundatum*	0	USA	Wolfenbarger (1953); Pritchard and Baker (1955); Smith Meyer (1987)
Paraplonobia contiguus	*Cynodon dactylon*	0	Pakistan	

Mite Species	**Turfgrass Host(s)**	**Alternate Hosts**	**Distribution**	**Other References**
Paraplonobia dactyloni	*Cynodon dactylon*	1	Yemen	Smiley and Baker (1995)
Petrobia latens	*Cynodon dactylon*	>100	Australia, New Zealand, USA, Central and South America,	
Petrobia waltheriae	*Cynodon dactylon*	2	Mexico	Tuttle *et al*. (1974, 1976)
Schizotetranychus cynodonis	*Cynodon dactylon, Distichlis stricta*	1	USA	McGregor (1950)
Schizotetranychus elymus	*Cynodon dactylon, Distichlis stricta*	15	USA, Mexico	McGregor (1950)
Schizotetranychus eremophilis	*Cynodon dactylon, Distichlis stricta*	7	USA, Mexico	McGregor (1950)
Schizotetranychus parasemus	*Cynodon dactylon, Distichlis stricta, Paspalum notatum*	3	USA, Brazil, Colombia, Poland	Pritchard and Baker (1955)
Schizotetranychus saba-sulchani	*Cynodon dactylon*	0	CIS (former Soviet Republics)	
Tetranychus attiahi	*Cynodon dactylon*	0	Egypt	Zaher *et al*. (1982)
Tetranychus gloveri	*Stenotaphrum dimidiatum*	87	Australia, Pacific Islands, USA, Central America & Caribbean, South America	
Tetranychus urticae	*Cynodon dactylon, Digitaria diversinervis, Pennisetum clandestinum, Stenotaphrum secundatum*	*c*. 930	Worldwide (Australia, Asia, Europe, North and South America)	

Tenuipalpidae. The family Tenuipalpidae (commonly called flat mites or false spider mites) are closely related to the Tetranychidae, and have long been neglected and overlooked in terms of their economic importance (Jeppson *et al.* 1975; Gerson 2008). All tenuipalpids feed on plants, usually infesting leaves but occurring also on fruit and, more rarely, on bark or on roots. The body is usually flat and varies in shape from ovoid (e.g. *Tenuipalpus*) to elongate, at least twice as long as wide in *Dolichotetranychus* (Plate 4). Typically, tenuipalpids are reddish (to yellowish) in colour and slow-moving.

Most tenuipalpids do not seem to cause any discernible injury to their hosts, but some are major crop pests, such as *Brevipalpus* spp. on citrus and *Dolichotetranychus* spp. on coconuts and pineapples (Gerson 2008). Host specificity varies, some species being associated with particular hosts while others are polyphagous and have been collected from a wide range of host plants; but, in general, tenuipalpids could be considered less host-specific than the Eriophyoidae (Ghai and Shenhmar 1984; Gerson 2008). Most *Dolichotetranychus* species have been collected from grasses. Mesa *et al.* (2009), together with Baker and Suigong (1988), catalogued 12 of the 23 described *Dolichotetranychus* species as coming from turf and similar warm-season grasses (Table 2), with another five species recorded from other grasses (Poaceae) and a reed species.

Compared with the 891 known species in the family Tenuipalpidae (Mesa *et al.* 2008), Smiley and Gerson (1995) listed a total of 18 tenuipalpid mite species as having been recorded in Australia, with only two *Dolichotetranychus* species, *D. floridanus* (a pest of pineapples) and *D australianus* (Smiley and Gerson 1995; Halliday 1999). The latter species was described by Womersley (1943) from specimens collected from a *Cynodon dactylon* bowls green in Gayndah, southern Queensland. *D. australianus* has also been reported from several locations in Egypt on *Cynodon dactylon* (Wafa *et al.* 1968-69; Mohamed *et al.* 1982[1]) and from Zimbabwe (Goldsmid 1962) and other parts of southern Africa (Smith Meyer 1979) on *Cynodon dactylon X transvaalensis* and *C. dactylon*. Based on the differentiation among *Dolichotetranychus* species in the USA and given the apparent geographical range of *D. australianus*, it is not unreasonable to speculate that future studies might identify additional species within the currently-recognised taxon.

In view of the *Dolichotetranychus* collections described later in this report, it is both interesting and relevant to note the collection details as reported by Womersley (1943):

> *"... the mites were" attacking the grass* Cynodon dactylon*, and confined their attentions to the nodes being protected by the leaf sheath. Affected grass becomes clumped and somewhat stunted in habit, although there is a general thickening of the stems. Runners are not produced and the grass eventually dies out leaving bare patches. On removal of the leaf sheath, the mites are found clustering in large numbers at the nodes, and are accompanied by a general brown discoloration. The mites are bright red in colour and move very sluggishly when disturbed. On account of their position within the leaf sheath, direct control measures are out of the question."*

[1] Identified as *Dolichotetranychus floridanus*, but assumed to be *D. australianus* because of the host species and other records from Egypt.

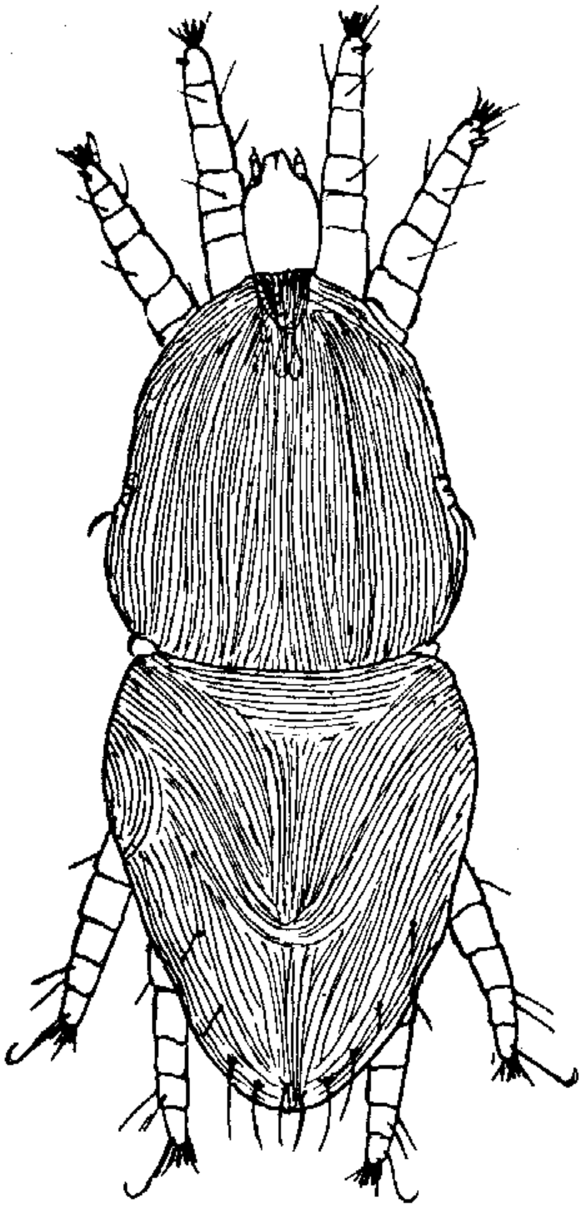

Plate 4. Dorsal view of female *Dolichotetranychus australianus* (from Womersley 1943).

Similar comments were expressed by Goldsmid (1962) in relation to infestations of *D. australianus* in Zimbabwe, though his initial imprecise reference to "grass" is perhaps suggestive of more than just *Cynodon* species being affected.

> Dolichotetranychus australianus *Womersley. Grass in the Salisbury [Harare] area is frequently found to be attacked by this small orange mite. Typical damage consists of a drastic shortening of the internodes, together with reduced leaf blades and sheaths.*
>
> *The mites can be found in large numbers at the bases of the sheaths. When infestation is severe, the grass tends to suddenly go brown and die.*
>
> *If the grass is examined with a hand lens, large numbers of eggs can be found at the leaf bases. Near the eggs many six-legged light orange-coloured larvae are often to be seen.*

Not much is known about the biology of these mites but, in the Federation, they seem to overwinter as small populations at all stages of development. At high temperatures, the incubation period of the eggs can be as short at five to seven days (at 91 degrees F.).

D. australianus *seems mostly to attack the finer grass varieties (e.g. Hall's improved).*

Symptoms associated with *D. zoysiae* are shown in Plate 5. These have been briefly described as follows:

"Mites of the new species were found to abundantly occur in the base of the leaf sheath, and to severely injure the host to markedly disturb its normal growth."

- Ehara (2004)

"We found an exceptional mite Dolichotetranychus zoysiae *Ehara on malformed leaves, but not healthy ones. It is assumed that some stimulus of the mite caused malformed leaves and stems in the turf species, which is the mite galls disease."*

- Akamine et al. (2005)

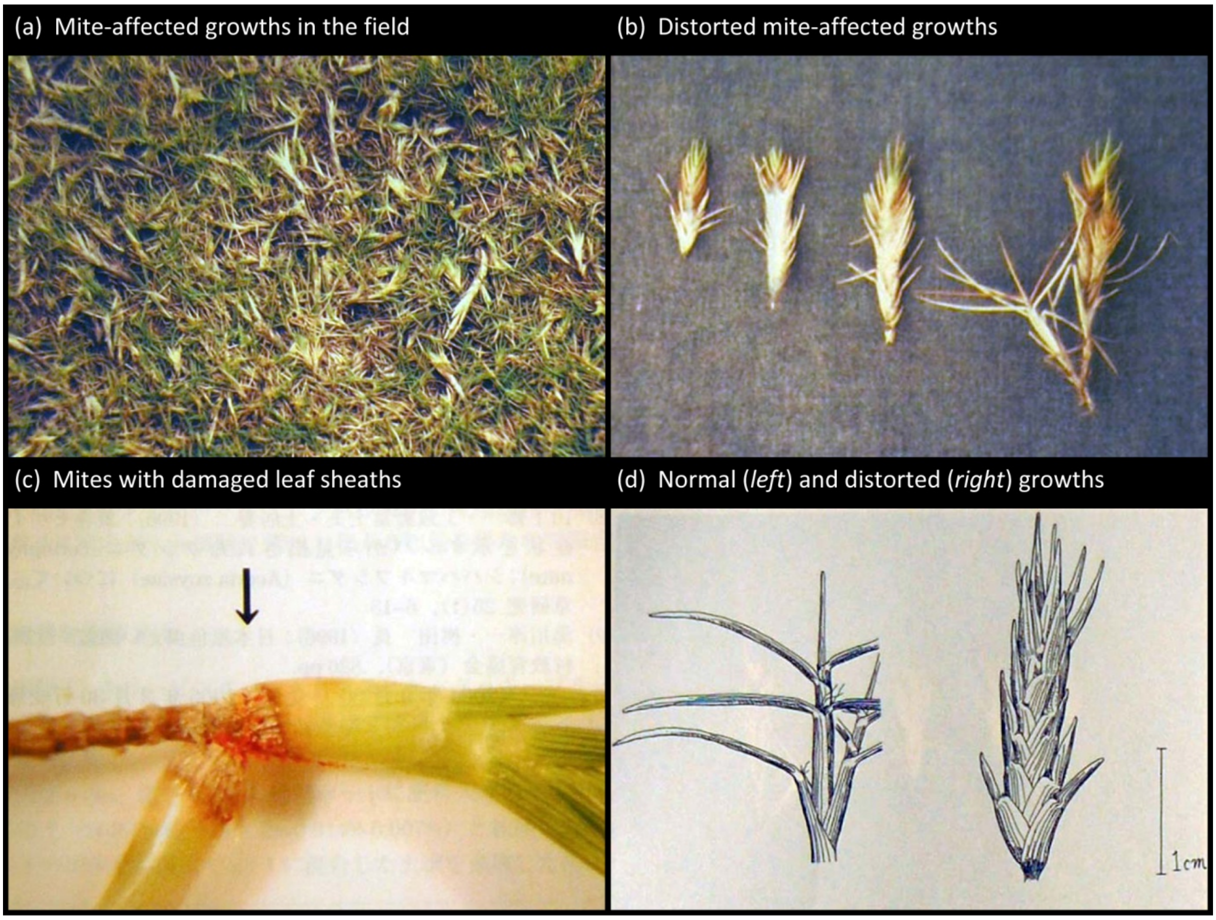

Plate 5. Symptoms of damage by *Dolichotetranychus zoysiae* on *Zoysia pacifica* (photographs from Akamine *et al.* 2005).

Crocker *et al.* (1981) reported witches' brooming on *Buchloe dactyloides* caused by the false spider mite, *Aegyptobia nomus*, following a particularly hot, dry period in Texas. The same mite species has also been recorded on *Distichlis stricta* and *Bouteloua gracilis*, and occurs in

Arizona, Florida, North Dakota, Texas and Utah (Crocker *et al.* 1981; Baker and Suigong 1988).

Basic data on the biology and ecology of tenuipalpid mites are poorly documented. Gerson (2008) summarised the generalised life cycle of false spider mites based on work with *Brevipalpus phoenicus*. This encompasses five stages - egg, larva, protonymph, deutonymph, and adult, and usually requires about 3–4 weeks (dependent on temperature and host plant). The males emerge first, their development being a few days shorter than that of the females. The build-up of its population is affected by both the high fecundity of young females and also the continuous (albeit lower) contribution from senescent mites, which lay eggs even after 6–7 weeks. Under stable conditions, very high populations can be reached. Developmental period and longevity, however, can be affected by crowding, as well as by temperature and the host plant: crowded females have been shown to reach adulthood faster, have higher mortality and a shorter life span than ‘uncrowded’ mites. Reproduction is usually by arrhenotoky, in which unmated females lay only male eggs whereas mated females produce both sexes.

In addition to their facilitation of disease entry via physical wounds inflicted on host plants, tenuipalpids have now been clearly established as vectors in the spread of fungal, viral and bacterial diseases (Gerson 2008). While previous work has been conducted with other genera, there is clearly the potential for this to occur with species of *Dolichotetranychus* also.

Although a number of predatory mites have been collected from tenuipalpid colonies, quantitative data on predators are often scarce and the controlling effect of the natural enemies has seldom been determined (Gerson 2008). A welcome exception is the study by Mohamed *et al.* (1982) of the predatory mite *Cheyletus cacahuamilpensis* in relation to its effects on populations of *Dolichotetranychus australianus*. However, instances of false spider mite control by natural enemies in the field appear to be rare for a variety of reasons, not least of which is the tendency of tenuipalpids to settle in enemy free refuges and protected or hidden sites, like leaf sheaths (Gerson 2008). Acaropathogenic fungi affecting tenuipalpids have sometimes been observed and trialled with promising results.

Ehara and Ueckermann (2006) described a new genus and species in the family Stigmaeidae, *Gymnostigmaeus akaminei,* from specimens collected on *Zoysia pacifica*[2] on Okinawa Island, Japan. These specimens were collected together with specimens of *Dolichotetranychus zoysiae*. Based on the general habits of stigmaeids in relation to phytophagous mites, they presumed *G. akaminei* to be an effective predator of the eggs of *D. zoysiae* which attacks *Zoysia* spp.

False spider mites are sedentary animals that move slowly, and because they usually scatter by walking, their dispersal is mostly limited to nearby host plants (Gerson 2008). How they disperse more widely (e.g. the role of wind) is still largely a matter of conjecture, though physical movement on machinery and contaminated plant material are risks that should be addressed in commercial practice.

[2] Host plant originally identified as *Z. tenuifolia*, but should be *Z. pacifica* from that area (Hotta and Kuroki 1994).

Eriophyidae

More than 7,000 species of plant-feeding mites are known worldwide, and about half of these are members of the superfamily Eriophyoidea, commonly called gall, bud, rust and eriophyoid mites (e.g. Lindquist *et al.* 1996; Walter and Proctor 1999; USDA Systematic Entomology Laboratory 2005). Within this, the major group (and the one of interest in this context) is the family Eriophyidae with around 300 genera and >3,000 species (Keifer *et al.* 1982; Walter 2006), including many important crop pests (e.g. *Aceria tosichella*, wheat curl mite) and species that transmit plant diseases, especially viruses (e.g. wheat streak mosaic virus transmitted by *A. tosichella*, ryegrass mosaic virus is transmitted by *Abacarus hystrix*). Some eriophyoids are leaf vagrants, but many form erinea (open fleece-like galls), witches' brooms, leaf edge rolls, big buds, pocket galls, blisters, and other forms of galling. Several genera such as *Aceria* (>800 species) are highly differentiated into species and contain many important plant pests.

Roughly three-quarters of the described eriophyoid species come from temperate areas (Walter and Proctor 1999). This indicates that the tropical world in general (de Lillo and Skoracka 2010), and Australia in particular (49 recorded species from the Eriophyidae – Halliday 1998), remain under-explored in terms of their eriophyoid mite fauna. Even New Zealand has more recorded *Aceria* species (30 - Manson 1984, 1989) than reported thus far for the much larger, geographically and botanically diverse Australian continent (17 species – Halliday 1998).

Eriophyoid mites are tiny, mostly less than 200 µm (0.2 mm) in length (Keifer *et al.* 1982; Walter and Proctor 1999). All post-egg stages have worm-like bodies with only two pairs of legs (which makes them unique among the mites). All are parasites of plants and most are highly host-specific (Lindquist *et al.* 1996), such that some species are seen as potential biological control agents for certain weeds (Smith *et al.* 2010). For example, Skorocka *et al.* (2010) were able to show from the available data that 80% of eriophyoids have been reported on only one host plant species, 95% on one host plant genus, and 99% on one host plant family. Although slow-walking, eriophyoid mites can disperse for long distances on air currents or specific animal carriers; and after landing on a plant, they can distinguish between suitable and unsuitable hosts (Michalska *et al.* 2010).

The mouthparts of eriophyoids cause only minor mechanical wounding, but this together with the injections of specific salivary secretions into host-cells results in specific responses and sets of characteristic symptoms. (Petanović and Kielkiewicz 2010). Mite feeding symptoms are generally rather specific, which can enable a rapid field diagnosis to be made (Keifer *et al.* 1982), rather than the prolonged and tedious job of sampling and identifying the mite species directly (although the latter is encouraged for an accurate diagnosis in case another eriophyoid species is involved).

Table 2. *Dolichotetranychus* species described from turfgrasses and other warm-season grass hosts (Baker and Suigong 1988; Mesa *et al*. 2008).

Mite Species	Host Plant	Originally Collected (Region & Country)	Other References
Dolichotetranychus australianus	*Cynodon dactylon*	Queensland, Australia	Womersley (1943)
Dolichotetranychus summersi	*Cynodon dactylon*	Arizona & California, USA	Pritchard and Baker (1952, 1958)
Dolichotetranychus apaches	*Cynodon dactylon, Distichlis stricta*	Arizona, Florida & North Carolina, USA	Baker and Tuttle (1972)
Dolichotetranychus carnea	*Buchloe dactyloides*, *Sporobolus* sp., *Distichlis* sp., *Muhlenbergia* sp.	Colorado, Idaho, North Dakota, New Mexico & Utah, USA	Pritchard and Baker (1952, 1958)
Dolichotetranychus cracens	*Sporobolus cryptandrus, Sporobolus* sp.	Oklahoma & Utah, USA	Pritchard and Baker (1958)
Dolichotetranychus macer	*Aristida namaquensis*	Cape Province, South Africa	Baker and Pritchard (1956)
Dolichotetranychus micidus	*Muhlenbergia asperifolia*	Colorado, USA	Baker and Pritchard (1956)
Dolichotetranychus muhlenbergia	*Muhlenbergia torreyi*	Arizona, USA	Baker and Tuttle (1972)
Dolichotetranychus salinas	*Distichlis spicata, Distichlis stricta*	Arizona, California & New Mexico, USA	Pritchard and Baker (1952, 1958)
Dolichotetranychus zoysiae	*Zoysia pacifica*[1]	Okinawa Island, Japan	Ehara (2004)
Dolichotetranychus repenae	*Panicum repens*	Tamil Nadu, India	
Dolichotetranychus tenellae	*Eragrostis tenella*	Tamil Nadu, India	

1 Host plant originally identified as *Zoysia tenuifolia*, but should be *Z. pacifica* from that area (Hotta and Kuroki 1994).

It has also been shown that eriophyoid mites can cause further secondary damage through the spread and entry of disease organisms. While eriophyoid species appear to be the most common phytophagous mites in vectoring virus diseases, it has also been shown that they can play a role in fungal pathogen epidemiology (Gamliel-Atinsky *et al.* 2010). In this regard, Butler's (1963) comment that summer blight fungus, *Bipolaris/Dreshlera*[3] sp., was almost always associated with bermudagrass mite (*Aceria cynodoniensis*) damage in his Arizona trials, so much so that some cases of grass death may have been due to the fungus rather than being caused directly by the feeding of the mites. The fungus was able easily to invade the chlorotic, distorted grass tissue and to progress rapidly in plants already weakened by mites.

Aceria cynodoniensis (bermudagrass mite, couch mite) is the eriophyoid mite species of major concern in warm-season turfgrasses by virtue of the fact that its host taxa, *Cynodon dactylon* and *C. dactylon X transvaalensis*, are the most important group of warm-season turfgrasses used worldwide. It was described by Sayed (1946) from infestations in Egypt (see also Plate 6), and has since been reported from the USA (initially as *A. neocynodonis* – see Plate 7) in all 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 *et al.* 2004, 2008), and from Zimbabwe (Goldsmid 1964), Australia (Gibson 1967; Halliday 1998), South Africa (Meyer 1968; Smith Meyer 1981a, 1981b) and Greece (Kapaxidi *et al.* 2008). However, it is not listed in the checklist by Xue and Zhang (2009) as having been recorded in South-East Asia. According to Smith Meyer (1981a, 1981b), *A. cynodoniensis* has also been recorded on *Pennisetum clandestinum* in South Africa. Early acarologists believed that the bermudagrass mite is native to Africa (Butler 1963; Johnson 1975); and more recent suggestions that it is probably native to Australia (Reinert 1982; Hudson *et al.* 1995) do not fit well with the time sequence of worldwide collections of the species nor with the presumed centre of origin for *Cynodon dactylon* located in the Middle East and its widespread distribution throughout Africa (Harlan and de Wet 1969).

General comments and descriptions of the symptoms observed by various early collectors and in different countries are shown below.

> *"...the mites live in the terminal leaf sheaths where they cause stunting, a witches-broom effect, and general decline of the grass."*
>
> \- Keifer (1960)

> *"The first noticeable damage to Bermuda grass was observed in the spring when lawns failed to begin their normal growth in spite of irrigations and applications of fertilizer. The grass that did appear was damaged by the mites and displayed a typical rosetting and tufting of the growth...caused by a shortening of the internodes and the apparent stimulation of abnormally excessive plant growth. The mites remained hidden under the leaf sheaths and varied in number from a few to a hundred or more under a single sheath. With heavy infestations the grass turned brown and died. Eventually the grass, in infested lawns, became greatly thinned out, allowing the growth of weeds....*
>
> *"Well-fertilized Bermuda grass was much more attractive to the mites than poorly fertilized grass. A soil fertility experiment...with closely mowed Bermuda grass was examined. All fertilized plots were heavily infested, as indicated by the typical swollen and brown stems. Unfertilized grass showed almost no injury.*

[3] The old name, *Helminthosporium*, was used in the original publication

"Examinations of large numbers of samples of mite-damaged grass...showed that summer blight fungus, Helminthosporium *sp., was always present. It seemed probable that the actual killing of large areas in mite-infested lawns was actually caused by this fungus rather than by the feeding of the mites. The fungus was able easily to invade the chlorotic, distorted grass tissue' and to progress swiftly in plants already weakened by the mites.*

"The mites appeared to be less abundant in lawns where flood irrigation was used. In general, infestations were most apparent on dry ridges and along the margins of the lawns. Lawns that were mowed closely showed the most injury, except for golf courses that received frequent close mowings. The shorter plants may be subjected to conditions of lower humidity when cut infrequently. In some cases the damage was more severe in shaded or partly shaded areas around the edges of the lawns. This might have been in part due to the stressed moisture condition of plants in these locations.

"An examination of Bermuda grass seed fields at Yuma indicated the prevalence of the mite around the edges and along irrigation ditches of some fields. Occasionally, it could be found in fields where the stand was sparse."

- Tuttle and Butler (1961)

"Lawn damage...consists of a "bunching" or "tufting" of the plants due to a shortening of the internodes. This species of mite seems to attack mostly the Cape Royal and Couch varieties of Cynodon dactylon *Pers., but has also been collected from the Hall's Improved variety."*

- Goldsmid (1964)

"Couch grass mite is found under leaf sheaths of terminal shoots. It causes a shortening of stolons and a proliferation of the terminal shoots which stand erect as a dense broom-like mass."

- Gibson (1967)

"A. [cynodoniensis] *is a serious pest of grass and can cause severe damage to lawns, golf courses, bowling greens and rugby grounds.*

"Because this microscopically small mite inhabits the sheaths of the grass it cannot be detected with the naked eye and therefore the start of an infestation is not observed before damage is serious. The mites cause stunting and bunching of the plants due to a shortening of the internodes. As the population increases a witch's broom effect can be seen. The result of a heavy infestation is that grass clusters...or rosettes are formed and there is a general decline of the plants.

"A well kept lawn would be able to support a light infestation of mites without suffering much damage. However, poorly kept grass and grass which is cut extremely short as is the case with many bowling greens, will suffer with even a light infestation. Therefore it is advisable not to cut the grass too short and to ensure that adequate fertilizer and water are applied."

- Meyer (1968)

"Infests the grass nodes, causing bunching and shortening of the leaves."

- Smith Meyer (1981a)

"The signs of damage by the grass rosette mite to lawns, putting greens, parks and bowling greens have been noticed in South Africa for a long time.... The mites occur in the

sheaths of the small grass blades, where they cause a stunting and distortion of the blades. In severe infestations, a rosette is formed...that arises from stunting of the internodes. Later this rosette becomes brown and eventually the grass completely dies.

Well-tended grass can withstand a light infestation, but neglected grass or grass that has been cut too short, as in many bowling greens, cannot withstand even a light infestation. Grass and lawns must be well fertilized, given sufficient water and not cut too short."

- Smith Meyer (1981b)

"Leaf sheath and stem gall caused by [Aceria] cynodoniensis....

"Infested grass exhibits a rosette symptom. Mite feeding apparently inhibits plant growth, in which the leaf sheaths become swollen, closely packed, thickened, and bunched at the stem node, and the leaf blades become stunted. Affected stems have greatly deformed and enlarged nodes and shortened internodes. The infestation showing the characteristic injury becomes evident in the spring on Bermuda grass in lawns and on golf courses; browning and thinning out of the grass follow."

- Keifer *et al.* (1982)

"Bermudagrass damaged by this hostspecific eriophyid mite first shows a slight yellowing of the tips of the grass blades, followed by a shortening of the internodes, producing a rosetted and tufted growth or witch's-broom effect.... When an infestation is severe, there is almost no green growth from the grass, and the tufts become a mass of large knots that die, causing brown, thin areas in the turf.... These dead or heavily damaged areas often become infested with weeds, thus creating other management problems.

- Reinert (1982)

"The mites feed and seek shelter in the leaf sheaths. Mite feeding apparently inhibits plant growth, thus the leaf sheaths become swollen, closely packed, thickened, and bunched at the stem node, and the leaf blades become stunted. Affected stems have greatly deformed and enlarged nodes and shortened internodes. The infestation showing the characteristic injury becomes evident in the spring on Bermuda grass grown in lawns; and then browning and thinning out of the grass follow."

- Kapaxidi *et al.* (2008)

"Bermudagrass damaged by this mite exhibits characteristic shortened leaves and internodes producing a typical rosetted and tufted growth or 'witch's broom' effect.... When a susceptible cultivar is infested, most of the terminal growth will become distorted and tufted and the infected stolons often die, but damage is usually accelerated when another stress (either biotic or abiotic) is present in the bermudagrass turf. If the mite infested grass is left untreated, large areas of bermudagrass are often killed."

- Reinert *et al.* (2008)

Photographs from Keifer *et al.* (1982) depicting the damage caused to *Cynodon* spp. by infestations of *A. cynodoniensis* are shown in Plate 8.

A second eriophyoid mite species, *Aceria cynodonis*, also affects *Cynodon* spp. in the USA, but has been reported only from California, Arizona, Kansas and Arkansas (Wilson 1959; Hall 1967; Keifer *et al*. 1982) and appears less damaging to bermudagrass than *A. cynodoniensis*. In Australia, we have not seen symptoms of mite damage with the appearance described below and depicted in Plate 9; this conclusion is supported by Halliday (1998).

"The mites confine themselves for the most part to the folded terminal shoot, where they are very abundant. A twisting of the folded terminal shoot and a subsequent infolding and twisting of the expanded blade occurs on heavily infested plants....

"Several other species of grasses in the vicinity of the infested Bermuda grass were examined for this species, but no mites were found."

- Wilson (1959)

"Kansas material, kept in the greenhouse, developed a heavy infestation which caused some stunting to the grass. Some shoots formed five or six successive loops."

- Hall (1967)

"Terminal shoot and leaf blade distortion caused by [Aceria] cynodonis....

"The mites are abundant in the folded terminal shoots, where their feeding apparently inhibits the expansion of the leaves. This results in the twisting of the folded terminal shoot and subsequent in folding, bending, and twisting of the leaf blade. Infested Bermuda grass may easily be recognized by the contorted terminal leaf blades.

- Keifer *et al.* (1982)

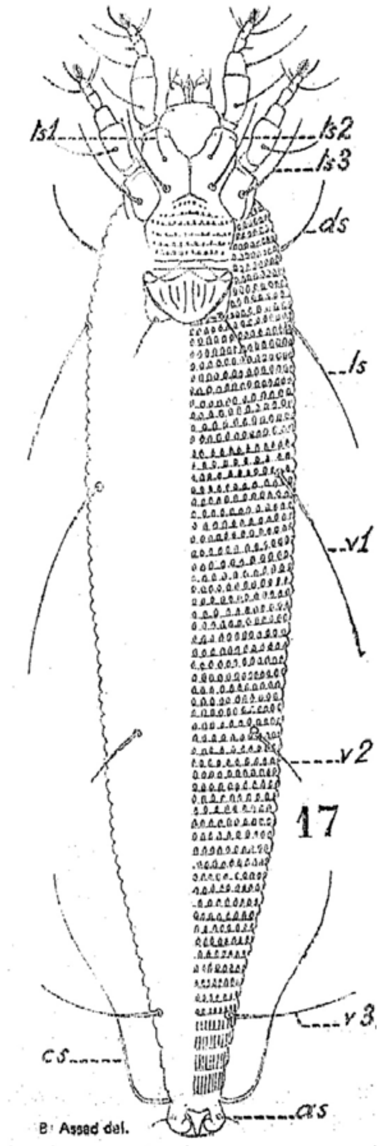

Plate 6. Line drawing of female *Aceria cynodoniensis* showing ventral aspect (*as*, accessory setae; *cs*, caudal setae; *ds*, dorsal setae; *ls*, lateral setae; *ts1*, thoracic setae I; *ts2*, thoracic setae II; *ts3*, thoracic setae III; *v1*, ventral setae I; *v2*, ventral setae II; *v3*, ventral setae III) (Fig. 17 from Sayed 1946).

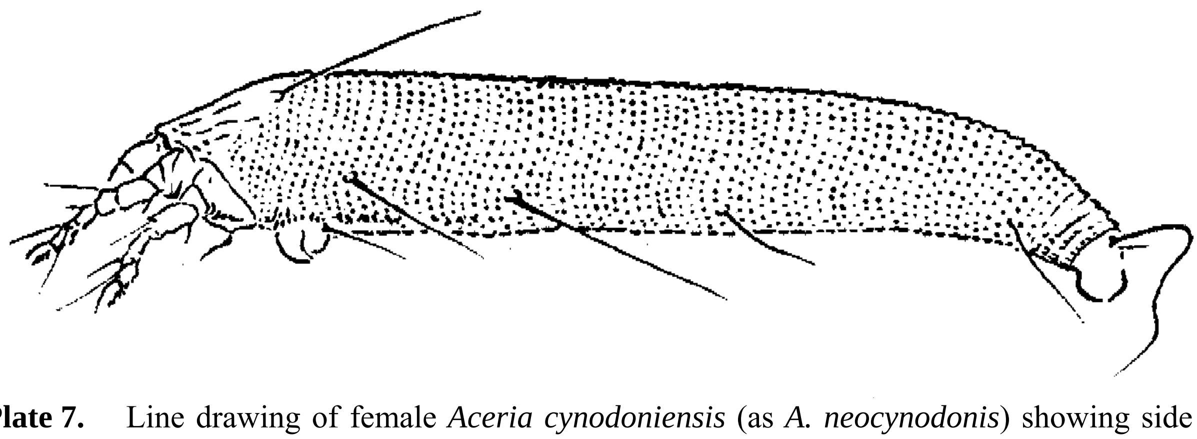

Plate 7. Line drawing of female *Aceria cynodoniensis* (as *A. neocynodonis*) showing side view (from Keifer 1960).

Plate 8. Photographs of rosetting (witches' brooming) on Bermuda grass infested with *Aceria cynodoniensis*; note closely packed swollen stem nodes (photographs A-C from Plate 35 in Keifer *et al.* 1982).

Abou-Awad and Nasr (1983) described two new eriophyoid species, *Abacarus cynodonis* and *Eriophyes (= Aceria?) niloticus*, found on *Cynodon dactylon* growing in the Sinai Peninsula. The *Abacarus cynodonis* mites appeared to be vagrants on the leaves, preferring the upper surface of the leaf blade causing curling of the leaves, while *E. niloticus* lives under broadened leaf bases. Combined infestations of these two mites can cause bending, stunting and twisting of the folded terminal shoots.

Aceria (= Eriophyes) zoysiae (the zoysiagrass mite) was first collected in the USA in 1982 (Baker *et al.* 1986; Reinert *et al.* 2004). It is native to the Pacific Rim countries including Japan and Korea. Although Xue and Zhang (2009) do not show *A. zoysiae* in their checklist of 325 South-East Asian eriophyoid species from 104 genera, it was identified by Yamashita *et al.* (1996) as the causal organism of a previously undescribed disease found widely on *Zoysia* spp. in Japan, and which may have been the subject of investigations dating back to Tahama's (1976) report of chlorotic leaf roll and terminal arching symptoms on *Z. japonica* in the field in Japan during 1973. *A. zoysiae* is now established across the USA from Maryland to California and Hawaii (Baker *et al.* 1986; Reinert *et al.* 2004). It reportedly damages a range of *Zoysia* spp., including *Z. japonica, Z. matrella, Z. sinica, Z. macrostachya* and *Z. pacifica*[2], with symptoms described as follows (see also Plate 10).

Plate 9. Twisted terminal shoots and leaves of Bermuda grass infested with *Aceria cynodonis* (photographs A-B from Plate 66 in Keifer *et al.* 1982).

A. zoysiae has not been recorded in Australia, and we have not seen symptoms on *Zoysia* spp. as described below. However, Manson (1989) described a new species, *Aceria zoysima*, from native *Zoysia minima* in New Zealand, which leads us to speculate that there could also be an undescribed species associated with the native *Zoysia macrantha* in Australia.

> *"Typical symptoms were white to yellow streaks and spots on newly emerging leaves, and rolling to the adaxial surface along one leaf margin.... In heavy infestations, the entire rolled leaf margin and most of the leaf was chlorotic. The rolled margin in older leaves became reddish yellow.*
>
> *"Mites in all stages of development were found on unexpanded leaves, on the leaf sheath and collar, and in the panicle and glume. Mites were abundant in rolled, expanding terminal shoots, where their feeding inhibited leaf expansion. New leaf tips and occasionally panicles were consequently twisted and caught in partially unrolled older leaves, resulting in terminal arches (buggy whip)...."*
>
> \- Baker *et al.* (1986)

> *"The typical symptoms showed white to yellow spots, streaks, and mosaic on newly emerging leaves, and curling along leaf margin."*
>
> \- Yamashita *et al.* (1996)

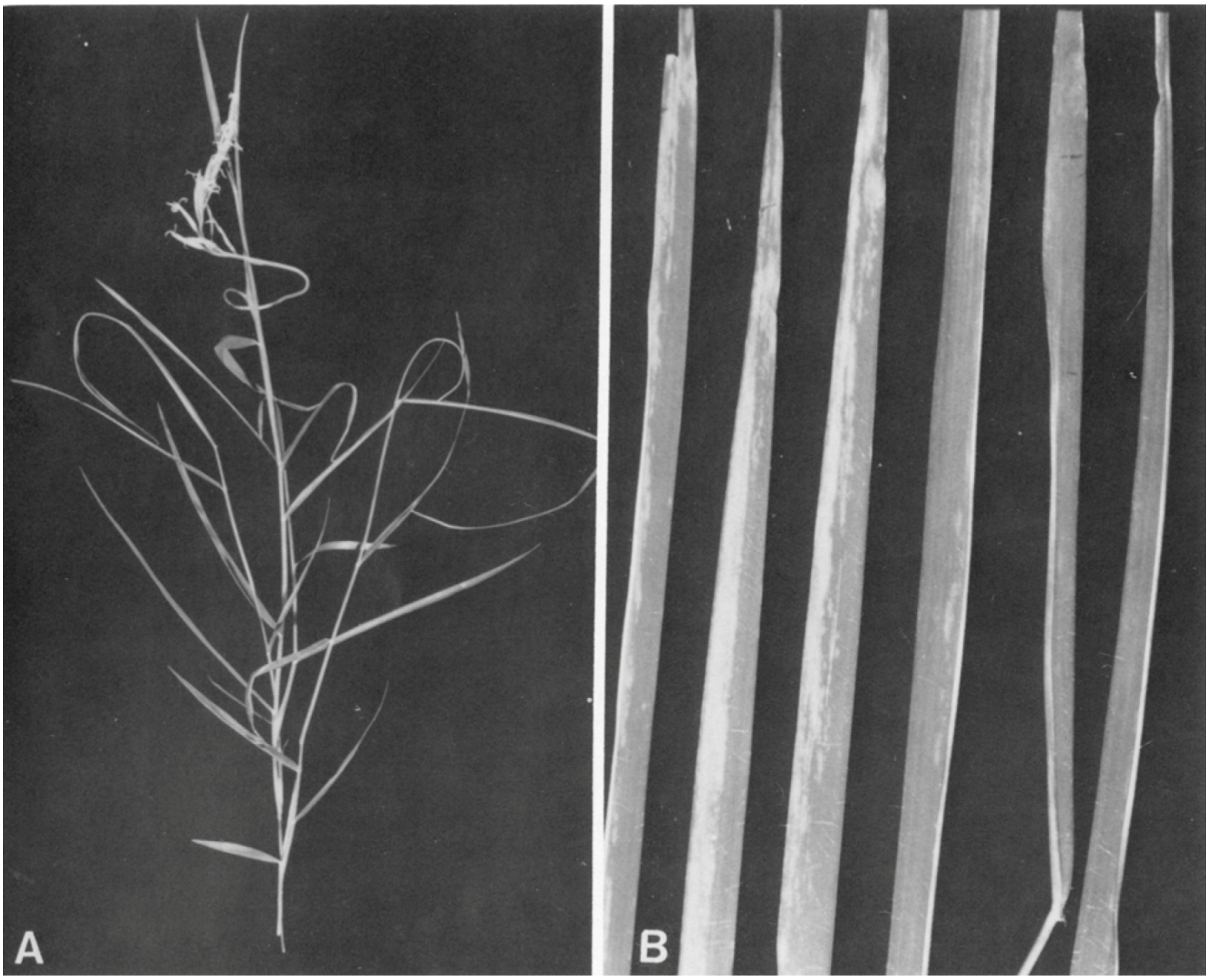

Plate 10. Typical buggy-whip symptom in panicle of *Zoysia japonica* infested by *Aceria zoysiae* (*left*); chlorosis and marginal leaf roll in *Z. japonica* foliage (*right*) (Fig. 1 from Baker *et al.* 1986)

The buffalograss mite, *Aceria slykhuisi* (described by Hall 1958), is host specific to buffalograss (*Bouteloua dactyloides*, syn. *Buchloe dactyloides*), which is native to the Central Plains of North America (Reinert *et al.* 2004). No detailed host resistance studies have been completed with this eriophyoid mite, but field observations and registration statements indicate that some cultivars are far more susceptible than others (Engelke and Lehman 1990; Reinert *et al.* 2004; Severmutlu *et al.* 2005). Symptoms are similar to those caused by *A. cynodoniensis* on bermudagrass (Hudson *et al.* 1995), except that only the female plants are visibly affected (Hall 1958)

> *"The stunting or witchbrooming seems to be due primarily to the feeding of the eriophyid mites, but almost as soon as these abnormalities are noticed, mites of the family Tarsonemidae appear and often become as numerous or more numerous than the eriophyids. The tarsonemid mites seemed to persist longer than the eriophyids. The abnormal growth or witchbrooming appears to be restricted to pistillate plants. Two test plots of grass...showed very convincingly that these mites are chiefly found on and cause abnormal growth of female plants....[The] stunted tufts of grass (witchbrooms) were very numerous in the female plants that were separated from a strip of staminate plants by only a few inches, the latter showing no growth deformities."*
>
> \- Hall (1958)

We found no reports of this mite occurring in countries outside of the USA, possibly because most, if not all, of the limited amount of planting material used in other countries would have been shipped as seed and should therefore be free of mites, particularly if de-hulled.

Studies of the life cycle and biology of the bermudagrass mite, *Aceria cynodoniensis*, have been conducted by Butler (1963) and Johnson (1975). The eggs and first nymphs are clear in colour and approximately one-third the size of an adult. The second nymph is approximately two-thirds the length of an adult with a whiter colour than the egg and first nymph. The adult is approximately 200 µm long, wormlike in shape, and whitish cream in colour. The mites remain under the leaf sheaths and vary in number from a few to a hundred or more under a single sheath. Observations on the development of the mite indicated that there are 3 instars. At 24±3°C, it took about 5-6 days from egg hatching through to adulthood. The whole life cycle is probably completed within 7-10 days, depending on the temperature. Hudson *et al.* (1995) state that mites are spread on grass clippings and have been observed hitchhiking on turf insects; dispersal by wind is also common.

Mites are most active during late spring and summer (Hudson *et al.* 1995). Butler (1963) reported some mortality under a laboratory temperature of 49°C for up to 6 hours per day, but concluded that high temperatures probably are not normally a severe limiting factor as the mites are often found in the sparse growth of lawns and on runners lying on concrete edging and kerbs with extremely high temperatures when exposed to direct sun. In spring, mite infestations often started on the southern sides of houses and brick walls; and as temperatures increased, infestations then sometimes moved to the shaded northern exposures. At low temperatures, mite development may be greatly retarded, if not stopped, on dormant bermudagrass. In the laboratory, high mortalities of both eggs and mites occurred at relative humidities of <80%. At the other extreme, mites drowned when droplets of water formed through condensation or fell on the plants. In the laboratory, bermudagrass mites migrated from cut infested bermudagrass that became dry, but in the field appeared to remain in grass that was stressed to wilting point.

For Butler (1963), one of the most perplexing aspects of his 3-year study on the bermudagrass eriophyoid mite in Arizona was that, time and again, untreated experimental plots showed almost complete reductions of the mites. He found that the tarsonemid *Steneotarsonemus spirifex* was frequently associated with reduced eriophyoid mite populations, the implications of which are explored in the following section.

Mites appeared to be less abundant in flood irrigated turf, although severe infestations were observed in flooded borders (Tuttle and Butler 1961; Butler 1963). In general, infestations were most apparent on dry ridges and along the margin of lawns. With sprinkler irrigation, mite infestations tended to be most severe along the edges and in areas not properly covered by the sprinklers. Mites could be killed in the laboratory by submerging the grass for several hours, and were even drowned in small containers by droplets of water. Lawns mowed closely at infrequent intervals sometimes showed the most mite injury, but this was not the case with frequent close mowing of turf on golf courses.

Apparently conflicting data have been presented on the effects on mites of fertilising lawns. Tuttle and Butler (1961) showed that grass well-fertilised with N was much more attractive to the mites than poorly fertilised grass in early autumn (September). Earlier in the season, however, it was observed that unfertilised grass was severely injured by mites while fertilised grass showed no apparent injury. Subsequent spring observations by Butler (196lb, 1962a, 1963) indicated that grass receiving fertiliser treatments showed less mite damage. So while high fertility levels in spring can reduce the amount of mite injury, possibly by helping the grass to out-grow the damage, highly fertilised grass is attractive to mites and can become severely infested. This is consistent with the recommendation by Hudson *et al.* (1995) to use irrigation and nutrition to help the grass to outgrow mite damage, because severe damage is usually associated with drought stress.

Over the past five decades, genotypes of bermudagrass have been evaluated for resistance in numerous trials in Arizona (Baltensperger 1961; Butler 1961a, 1962a, 1963; Butler and Kneebone 1965), Florida (Johnson 1975; Reinert *et al.* 1978), Georgia (Hanna and Braman 2009) and Texas (Reinert *et al.* 2004, 2008; Reinert 2010). FLoraTeX bermudagrass, for example, showed no infestation of bermudagrass mite in a 6-year study, and was released for its resistance to both mites and other abiotic and biotic stresses (Dudeck *et al.* 1994). However, while varietal responses can vary from little or no effect of mite infestation through to severe damage in susceptible genotypes, results have not always been consistent from year to year and from trial to trial. This highlights the need for a better understanding of exactly how mites affect the plant and therefore the factors and plant parameters that contribute to mite resistance, thus improving both the selection and management of varieties.

Tarsonemidae

The family Tarsonemidae covers a wide range of feeding behaviour. Some are parasites of insects and other animals, predators of mite eggs, and plant feeders; most, however, feed on fungi and algae, and may have a sporotheca (a special spore-carrying structure) for carrying a specific fungus on which they feed (Ochoa *et al.* 1991). They are small, rapid moving and migratory animals, which makes field diagnosis difficult.

Smiley *et al.* (1993) list 14 mite species of the genus *Steneotarsonemus* known to infest graminaceous plants, the more important of which in the present context are shown in Table 3. Only 2 *Steneotarsonemus* species, *S. ananas* and *S. bancrofti* (pests of pineapples and sugarcane, respectively), have been recorded among a total of 9 tarsomenid species in Australia (Halliday 1998).

The reported symptoms from infestations vary. *Steneotarsonemus* (as *Parasteneotarsonemus) panici* and *S. aristidae* are found beneath the leaf sheaths on *Panicum repens* and *Aristida setaceous*, respectively, where both cause rusting symptoms (Mohanasundaram 1984); *S. konoi* causes necrosis of the stems and flowers of *Cynodon dactylon* (Smiley and Emmanouel 1980); and *S. spirifex* is found within the leaf sheath of *Cynodon dactylon*, causing thickening of nodes and a witches broom effect (Mohanasundaram 1984).

Butler's (1963) studies on the biology of the bermudagrass mite *Aceria cynodoniensis* (= *A. neocynodoniensis*) showed that the tarsonemid *Steneotarsonemus spirifex* was the organism most frequently associated with reduced eriophyoid mite populations. This suggests some sort of relationship between the two, perhaps even involving some form of biological control. Beer (1963), for example, found that two species of *Steneotarsonemus* were involved in the exploitation of galligenous tissues caused by two species of eriophyoid mite, one on poplar and one on birch. The tarsonemid mites invaded the galls caused by the eriophyoids. The galls were abandoned by the eriophyoids and the tarsonemids then utilised the gallingenous tissue as a food source. This relationship was interpreted as an unusual form of social parasitism, and Butler (1963) suggested that something similar may be happening between *A. cynodoniensis* and *S. spirifex*. The similarity of Hall's (1958, 1967) observations regarding the association of tarsonemids with eriophyoid infestations on *Buchloe dactyloides* again supports some sort of relationship between the two groups.

Useful Websites

The following three websites provide the most accurate, detailed and useful material for people wishing to search on-line for further information on mites.

Acari: The Mites
(http://tolweb.org/tree?group=Acari&contgroup=Arachnida)
This site provides a brief overview prepared by Drs David Walter, Gerald Krantz and Evert Lindquist as part of The Tree of Life Web Project. It also has live links to the University of Queensland's Mite Image Gallery (set up by Dr Walter) and the following USDA website.

Acari. *Mites and Ticks: A Virtual Introduction*
(http://www.sel.barc.usda.gov/acari/index.html)
Worldwide, there are approximately 7,000 known species of plant-feeding mites. This 'MiteSite', hosted by the UDSA's Systematic Entomology Laboratory, has short well-illustrated webpage articles on 6 different groups of these plant-feeding mites.

Invasive Mite Identification: Tools for Quarantine and Plant Protection
(http://keys.lucidcentral.org/keys/v3/mites/Invasive_Mite_Identification/key/Whole_site/Home_whole_key.html)
This site, authored by Dr David Walter, is the most detailed of the available websites, with interactive keys, a glossary in which >700 acarine terms are defined, and 28 well-illustrated fact sheets covering the different mite groups.

Australasian Arachnology
(http://www.australasian-arachnology.org/arachnology/)
This site, hosted by the Australasian Arachnological Society, has an on-line version of Dr Bruce Halliday's (2008) paper, as well as good introductory articles on 8 other arachnid groups.

Table 3. Phytophagous mites of the family Tarsonemidae recorded on warm-season turfgrasses and similar grass species (Smiley *et al.* 1993).

Mite Species	Turfgrass Host(s)	Alternate Hosts	Distribution	Other References
Steneotarsonemus aristidae	*Aristida setaceous*	0	India (Tamil Nadu)	Mohanasundaram (1984)
Steneotarsonemus furcatus	*Paspalum* sp.	1	Florida, Costa Rica, E1 Salvador, Venezuela	De Leon (1956)
Steneotarsonemus hordei	*Cynodon* sp.	>5	Greece	Emmanouel and Smiley (1985)
Steneotarsonemus hyaleos	*Distichlis spicata*	0	California	Beer (1954)
Steneotarsonemus konoi	*Cynodon dactylon*	4	California, Greece	Smiley and Emmanouel (1980)
Steneotarsonemus panici	*Panicum repens*	0	India (Tamil Nadu)	Mohanasundaram (1984)
Steneotarsonemus paspali	*Paspalum* sp.	0	Florida	De Leon (1956)
Steneotarsonemus spirifex	*Cynodon dactylon*, *Buchloe dactyloides*	3	Western USA, Austria, India (Tamil Nadu)	Mohanasundaram (1984)

REVIEW OF COMMERCIAL INFORMATION

In practice, commercial product suppliers are currently, and almost exclusively, the source of 'information' on turfgrass mites for sod producers and turfgrass managers in the course of supplying those products. In the context of this report, it is therefore appropriate to assess the accuracy and value of such information.

The couch mites page on the Living Turf website (http://www.livingturf.com.au/couch-mites-a-turf-pest-profile.php) acknowledges the contribution of Syngenta to the information presented. There is confusion regarding the species name: *Aceria (= Eriophyes) cynodoniensis* and *A. cynodonis* (mis-spelled as *A. cynodontis)* are two separate species with different geographical distributions and effects on *Cynodon* spp. Otherwise, the information provided essentially follows the standard American account for *A. cynodoniensis* (e.g. Buss 2008). This was largely reproduced by Kirby (2009, 2011) in Turf Producers Australia publications, but referred to *A. cynodontis*, which is doubly in error (i.e. the wrong species and mis-spelled name). Kirby (2011) has also added a photograph of 'couch mite damage' showing instead an infestation of grass webbing mite (*Oligonychus* sp.), a distantly-related species with completely different behaviour and effects.

Syngenta (2009) presents similar US-based information on the Bermuda/couch grass mite (now incorrectly called *Eriophyes cynodoniensis* rather than *Aceria cynodoniensis*) on their Green Cast website. However, in an earlier Green Cast note on grass webbing mites, Syngenta (2008) refers to the Banks grass mite (*Oligonychus pratensis*) which has not been recorded in Australia (Halliday 1998).

The PDF Insect Identification Guide on the Nuturf website (http://www.nuturf.com.au/new%20design/turfflyers/technical/Insect%20Identification%20Guide%201.pdf) depicts a Tetranychid mite image beside a couch stolon apparently showing eriophyoid mite damage. The caption below reads 'Mites - *Oolicotetranychus*, *Eriophyes* spp.' The former genus is an apparent mis-spelling of *Dolichotetranychus* or *Oligonychus* as discussed further below (but the left-hand picture is clearly not of a *Dolichotetranychus* species) and the latter is an alternative genus name no longer used in relation to eriophyoid couch mites.

The recent registration of Thumper (20 g/L formulation of abamectin) for couch mite control is a welcome advance, though personal experience in using abamectin (an adulticide) for this purpose on turf trials over the past decade (D.S. Loch, unpublished observations 2001-10) suggests that this is part of the answer rather than a complete answer to couch mite control. However, it also needs to be borne in mind that abamectin is toxic to predatory Phytoseiid and Tydeid mites (Lindquist *et al.* 1996), such that its widespread or continued use could upset delicate natural balances that otherwise might contribute naturally to the control of phytophagous mites. Of perhaps greater concern is the extremely poor presentation in commercial brochures of the trial data used for registration of abamectin and by Kirby (2011). The original brochure referred to the couch mite species as *Oolicotetranychus austrianus*, an apparent double mis-spelling of the Tenuipalpid *Dolichotetranychus australianus* or perhaps the Tetranychid webbing mite *Oligonychus araneum*; not surprisingly, reference to the scientific name has since been removed and the current brochure (Turf Culture 2010) makes mention only of couch mite. (Similarly, the registered label refers only to couch mite.) The data presented are described as 'Couch Mite Populations', but the unit area is not defined nor is it clear what specific attribute was actually measured and how. Based on Butler's (1963) informed comment that the number of mites under a single leaf sheath can vary from a few to more than 100, the numbers shown on the Y-axis are simply too small to be referring to numbers of actual mites recovered from even a very small area. If instead the intention is to refer to numbers of mite affected growths (i.e. rosetted tiller terminals) as reported by Reinert *et al.* (1978, 2008) and Reinert (2010), such deformed growths are persistent in the sward so that the numbers of affected growths would not readily show a decline over the 10-40 day period as depicted by the graph in Figure 1. Some of the same data were also presented by Kirby (2011) in Turf Guide 2011, but without any caption at all on the Y-axis to indicate what measurement the numbers refer to.

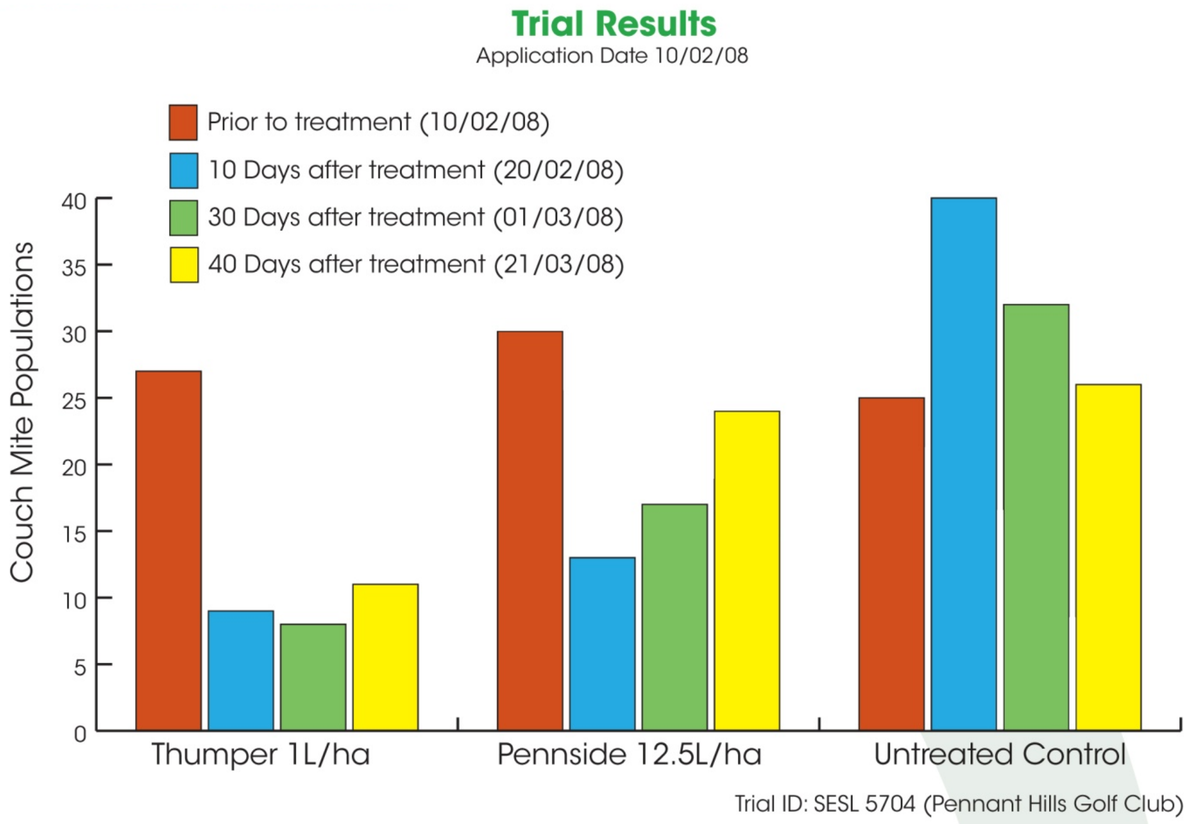

Figure 1. Thumper trial results (from Turf Culture 2010).

The account of couch mite by Spencer (2009) in *Pitchcare* has been cut and pasted from Buss (2008) who was writing from American experience, together with a photograph of eriophyoid mite activity taken from the Living Turf website. Information on abamectin was added from other sources (mainly http://www.420magazine.com/forums/problems-pests-disease-control/134690-using-miticide-kill-spidermites.html or equivalent internet article) following the registration of Thumper in Australia.

In summary, commercial information on turfgrass mites in Australia is focussed almost exclusively on eriophyoid mites and based on American literature; there is no mention of, and no information on, the tenuipalpid mites which also pose very serious problems for turf producers and managers. While the original Australian website seems reasonably accurate in the information presented, albeit American and eriophyoid in flavour, accounts derived from this are confused and inaccurate in terms of the actual species involved. 'Scientific' data generated by commercial suppliers is also of poor, even doubtful, quality. These issues should be taken into account by turf producer and turf manager groups when seeking information and guidance in relation to turfgrass mites in the future.

MATERIALS AND METHODS

Members of the field survey team were experienced and well credentialed turfgrass scientists. Their expertise in turf matters was balanced by the necessary laboratory and taxonomic skills of an acarologist who is experienced in the identification of plant-feeding mites, especially those belonging to the superfamily Eriophyoidea.

Prior to the survey starting officially, the field survey team spent a one-day preliminary training course with Ms Knihinicki at the Agricultural Institute, Orange, NSW to understand the processes of mite extraction and identification. The team also discussed how field samples should be collected and shipped to maximise the chances of successful processing in the laboratory. The start of sample collection was delayed because of prior commitments by Ms Knihinicki on other projects. Unfortunately, the main period of sampling then coincided withn the extreme La Niña pattern that brought extremely wet conditions to the eastern states, making collections more difficult during the summer and autumn of 2011-11.

Because the mites causing damage in turf generally live within the leaf sheaths of grasses, it is very difficult to extract them from their vegetative bases. Techniques such as using a heat source above the sample (e.g. a light bulb) suspended over a conical funnel under which is a preservative collecting fluid are not applicable.

In dealing with the turfgrass mites, the preference was to place each plant sample into a screw-capped plastic container with 70% ethanol (water + ethanol). Shaking this for approximately 2 minutes extracted any mites that were present into the supernatant liquid. Sometimes partial maceration of the plant material was undertaken to assist with the release of mite specimens. The mixture was then filtered through a micropore filter pad with the assistance of vacuum suction. To carry out this process effectively, it is vital to limit the amount of soil contaminant in the sample because this easily becomes trapped on the micropore filter pad (hence, preliminary coarse filtering is sometimes necessary to limit such contamination). The micropore filter pad was then examined under a stereo microscope and the mites were picked off and mounted on microscope slides for detailed examination under a compound microscope.

Although it is possible to distinguish the general group to which the extracted mites belong under the stereo microscope (with magnification at about 160X), higher magnification levels are necessary to distinguish eggs, larvae and adults in greater detail. However, deciding exactly which mites are present can be very difficult because some larval stages of mites can easily be confused with the adult stages of other species.

The preferred method of field sampling was for the plant samples to placed into 70% ethanol in the laboratory soon after collection to prevent deterioration. With the examination of samples taking place in the laboratory in Orange NSW, preservation of specimens was an issue because Australia Post restricts the transport of flammable liquid such as ethanol. In this case, field samples were wrapped in damp paper towel, placed in zip-sealed plastic bags, and cooled to c. 4°C as soon as practicable. At the start of a week, the refrigerated samples were sent by Express Post to the Orange Agricultural Institute, Orange NSW.

While this method of collecting and forwarding samples had some occasional failures, it worked well most of the time. The major drawbacks were that Australia Post has no facility to refrigerate or cool samples in transit, and it can take between 2 and 4 days for samples to arrive in Orange (classified as a non-capital city postal centre). The condition of a collected sample greatly affected its appearance upon arrival for inspection (e.g. overly wet material tended to deteriorate more quickly in the post, samples contaminated with soil were much more difficult or impossible to examine). Such limitations, plus soil contaminants, meant that some samples had deteriorated to, or were in, a less than desirable condition prior to laboratory examination.

Mites tend to be spread unevenly over an area, with “hot spots” where the infestations are greatest. Because of this, samples were taken where and when the symptoms of mite damage were seen, rather than trying to collect at random across a paddock. Wherever possible, GPS coordinates and preceding weather conditions were recorded for each collection site, as well as photographic records of the damage taken. GPS coordinates for the remaining samples were obtained by using the physical address to determine the coordinates through Google Earth.

Some samples were checked under a dissecting microscope before being submitted for extraction and identification. This also enabled photographs to be taken of mites and their eggs, particularly of the *Dolichotetranychus* species. Investigations also commenced into the applicability of new and inexpensive digital technology in the form of a USB microscope for field monitoring and use by turf growers and facility managers (see Appendix 1).

RESULTS

Full collection and identification details for all individual samples taken in the course of our survey are shown in Table 4. Overall, 40% samples came from turf farms, with a further 29% collected from various non-sporting urban sites and 13% from sports facilities (Table 5).

Overall, 27.7% of samples failed to arrive in good condition for extraction. Of the 119 samples submitted for identification, 6 were unusable for various reasons on arrival in Orange: too decomposed because held too long before sending (2 samples, unnumbered) or deteriorated in transit because of excess moisture (77, 88) or postal delays (98, 101). A number of other samples that arrived in poor condition (78, 79, 80, 81, 82, 83, 89, 91, 92, 97, 102, 104) or had some soil contamination that made separation difficult (62, 66, 86, 100, 105, 109, 110, 112, 113, 116, 117) were routinely extracted without finding any phytophagous mites, though suspected fungal and/or detritus feeders were detected in 4 of these samples (78, 82, 103, 117). Only 3 samples in poor condition (84, 93) or with soil contamination (67) yielded phytophagous mites; and in one of those samples (84), the identification was inconclusive.

A further 42 samples yielded no mites and another 12 had only fungal and/or detritus feeders with possibly some predatory mites. An examination of the data in Table 4 suggests that the proportion of samples without any phytophagous mites increased over the course of the summer-autumn of 2010/11 and that the number of other mites (mainly fungal and detritus feeders, plus some predatory mites), including tarsonemids, increased over this period.

Despite this apparent trend, 50% or more of *Cynodon* and kikuyu (*Pennisetum clandestinum*) samples and 40% of *Zoysia* samples yielded phytophagous mites (Table 6). The major exception was buffalo grass (*Stenotaphrum secundatum*) where no plant-feeding mites were extracted from any of the samples submitted. Similarly, no potentially-damaging mites were recovered from seashore paspalum (*Paspalum vaginatum*), but this was not unexpected given the dearth of previous reports of phytophagous mite activity on this species overseas.

For *Cynodon*, the number of samples with phytophagous mites was almost evenly divided between *Dolichotetranychus* (Tenuipalpidae) and *Aceria* or *Abacarus* (Eriophyidae) species. However, based on our results, kikuyu appears to be infested exclusively by *Dolichotetranychus* species; sampling from both *Cynodon* and kikuyu in mixed swards failed to detect any *Aceria* species in kikuyu, which is contrary to South African reports (Smith Meyer 1981a, 1981b) that *A. cynodoniensis* also infests kikuyu grass. Both these grass species, however, showed infestation by *Dolichotetranychus* species (and perhaps the same one) in a mixed sward sampling at Murrarie (QLD).

The single instance of phytophagous mite found in blue couch (*Digitaria didactyla*) was of a *Dolichotetranychus* species, which is perhaps consistent with the high host specificity typical of the Eriophyidae and the generally wider host ranges shown by the Tenuipalpidae. This was part of a mixed-sward sampling in Perth (WA) that failed to show infestation of the closely-related weed grass *Digitaria sanguinalis* and *Cynodon dactylon*, though detritus-feeding oribatid mites were extracted from the latter species perhaps suggesting that the material sampled was too old or that the oribatid mites may have already been present around the root area of the plants.

Table 4. Collection and identification details for individual samples taken during the survey of turfgrass mites.

Sample #	Host Species	Variety	Location	State	Latitude, Longitude	Collection Date	Damage Symptoms	Mites Present	
								Family/Suborder	Genus
1	*Zoysia matrella*	Shadetuff	Gordonvale	QLD	17°08'S 145°43'E	25-Aug-10	Distorted growths	Eriophyidae	*Aceria*
2	*Zoysia japonica*	Ozeboy	Gordonvale	QLD	17°08'S 145°43'E	25-Aug-10	Distorted growths	Eriophyidae	*Aceria*
3	*Zoysia pacifica*	Common	Gordonvale	QLD	17°08'S 145°43'E	25-Aug-10	Distorted growths	Tenuipalpidae	*Dolichotetranychus* (close to *australianus*)
4	*Pennisetum clandestinum*	Common (seeding)	Rosehill	NSW	33°50'S 151°01'E	01-May-10	Distorted growths	Tenuipalpidae	*Dolichotetranychus* (close to *australianus*)
5	*Pennisetum clandestinum*	Common (seeding)	Keysborough	VIC	37°59'S 151°01'E	01-Nov-10	Distorted growths	Tenuipalpidae	*Dolichotetranychus* (close to *australianus*)
6	*Pennisetum clandestinum*		Orange	NSW	33°19'S 149°05'E	03-Nov-10	Distorted growths	-	-
7	*Pennisetum clandestinum*	Common (seeding)	Hastings Point	NSW	28°22'S 153°35'E	25-Nov-10	Badly distorted growths; no new growths seen	Acaridae	*Tyrophagus* (fungal feeder)
8	*Paspalum vaginatum*	SeaDwarf	Coffs Harbour	NSW	30°16'S 152°59'E	25-Nov-10	Looping stolons not connected to the ground	Cryptostigmata	Unknown
9	*Cynodon dactylon*	Wintergreen	Rochedale	QLD	27°34'S 153°09'E	13-Nov-10	Pinetree-like growths in patches of poor growth	Tenuipalpidae	*Dolichotetranychus*
10	*Cynodon dactylon*	Wintergreen	Rochedale	QLD	27°34'S 153°09'E	13-Nov-10	Witch's brooming; stolons poorly rooted down	Tenuipalpidae	*Dolichotetranychus*
11	*Cynodon dactylon X transvaalensis*	MiniVerde	Cleveland	QLD	27°31'S 153°15'E	13-Nov-10	Pinetree-like growths	Eriophyidae	*Aceria*
12	*Cynodon dactylon X transvaalensis*	Champion Dwarf	Cleveland	QLD	27°31'S 153°15'E	13-Nov-10	Pinetree-like growths	Eriophyidae	*Aceria*
13	*Cynodon dactylon X transvaalensis*	FloraDwarf	Cleveland	QLD	27°31'S 153°15'E	13-Nov-10	Pinetree-like growths	Eriophyidae	*Aceria*
14	*Cynodon dactylon X transvaalensis*	Novotek	Gordonvale	QLD	17°08'S 145°43'E	13-Nov-10		Cryptostigmata	Oribatid mite (detritus feeder)
15	*Zoysia pacifica*	Common	Gordonvale	QLD	17°08'S 145°43'E	13-Nov-10		Acaridae	Fungal feeder

Sample #	Host Species	Variety	Location	State	Latitude, Longitude	Collection Date	Damage Symptoms	Mites Present	
								Family/Suborder	**Genus**
16	*Zoysia matrella*	VN003	Rochedale	QLD	27°34'S 153°09'E	13-Nov-10	Witch's brooming; stolons poorly rooted down	-	-
17	*Zoysia matrella*	Diamond	Rochedale	QLD	27°34'S 153°09'E	13-Nov-10	Witch's brooming; stolons poorly rooted down	Tenuipalpidae	Possibly *Dolichotetranychus* (nymphs)
18	*Zoysia matrella*	Zorro	Rochedale	QLD	27°34'S 153°09'E	13-Nov-10	Witch's brooming; stolons poorly rooted down	-	-
19	*Zoysia matrella*	Emerald (NQ genotype)	Rochedale	QLD	27°34'S 153°09'E	13-Nov-10	Witch's brooming; stolons poorly rooted down	-	-
20	*Zoysia matrella*	Shadetuff	Rochedale	QLD	27°34'S 153°09'E	13-Nov-10	Witch's brooming; stolons poorly rooted down	-	-
21	*Zoysia japonica X tenuifolia*	PristineFlora	Rochedale	QLD	27°34'S 153°09'E	13-Nov-10	Witch's brooming; stolons poorly rooted down	-	-
22	*Zoysia japonica*	Empire	Rochedale	QLD	27°34'S 153°09'E	13-Nov-10	Witch's brooming; stolons poorly rooted down	Acari	Unknown, 1 specimen only
23	*Zoysia pacifica*	Common	Alexandra Hills	QLD	27°33'S 153°14'E	13-Nov-10	Witch's brooming; stolons poorly rooted down	Eriophyidae	*Aceria*
24	*Pennisetum clandestinum*	Oakridge	Rochedale	QLD	27°34'S 153°09'E	13-Nov-10	Witch's brooming; stolons poorly rooted down	-	-
25	*Stenotaphrum secundatum*	Palmetto	Chambers Flat	QLD	27°46'S 153°05'E	16-Dec-10	Crab-like growth (stolons not rooted down); some witch's brooming	-	-
26	*Digitaria didactyla*	Aussiblue	Chambers Flat	QLD	27°46'S 153°05'E	16-Dec-10	Poorly rooted stolons	-	-
27	*Pennisetum clandestinum*	Common (seeding)	Coldstream	VIC	37°41'S 145°27'E	11-Jan-11	Proliferation of multiple growths; individual shoot tips clubbed (swollen, constricted)	Phytoseiidae Tenuipalpidae	Predatory mite (Phytoseiidae) *Dolichotetranychus*
28	*Pennisetum clandestinum*	Common (seeding)	Narrabundah, Canberra	ACT	35°20'S 149°09'E	09-Jan-11	Distorted stolon growth, shortened internodes, poorly rooted	Tenuipalpidae	*Dolichotetranychus*
29	*Pennisetum clandestinum*	Common (seeding)	Maroubra	NSW	33°57'S 151°14'E	24-Jan-11	Stunted bunchy growth	-	-
30	*Cynodon dactylon*		Concord	NSW	33°50'S 151°06'E	24-Jan-11	Witch's brooming	-	-

Sample #	Host Species	Variety	Location	State	Latitude, Longitude	Collection Date	Damage Symptoms	Mites Present	
								Family/Suborder	Genus
31	*Cynodon dactylon*		La Perouse	NSW	33°59'S 151°13'E	24-Jan-11	Stunted & distorted growth	Eriophyidae	*Aceria*
32	*Pennisetum clandestinum*	Common (seeding)	Bertram	WA	32°15'S 115°51'E	08-Feb-11		Tenuipalpidae	*Dolichotetranychus*
33	*Pennisetum clandestinum*	Common (seeding)	Pinjarra	WA	32°36'S 115°52'E	08-Feb-11		Tarsonemidae	1 x female (need males for ID)
34	*Stenotaphrum secundatum*		Bertram	WA	32°15'S 115°51'E	08-Feb-11		? Stigmaeidae	? Predatory mite
35	*Cynodon dactylon*		Bertram	WA	32°15'S 115°51'E	08-Feb-11		Tenuipalpidae	*Dolichotetranychus*
36	*Cynodon dactylon*		Pinjarra	WA	32°36'S 115°52'E	08-Feb-11		Eriophyidae Acaridae	*Abacarus* *Tyrophagus*
37	*Cynodon dactylon*		Fremantle	WA	32°03'S 115°45'E	08-Feb-11		-	-
38	*Cynodon dactylon*		North Perth	WA	31°56'S 115°51'E	09-Feb-11		-	-
39	*Digitaria sanguinalis*		North Perth	WA	31°56'S 115°51'E	09-Feb-11		-	-
40	*Digitaria didactyla*		North Perth	WA	31°56'S 115°51'E	09-Feb-11	Stolons not rooted down	Tenuipalpidae	*Dolichotetranychus*
41	*Cynodon dactylon*		North Perth	WA	31°56'S 115°51'E	09-Feb-11	Pinetree-like growths	Cryptostigmata	Oribatid mite (detritus feeder)
42	*Stenotaphrum secundatum*	Jabiru	Shenton Park	WA	31°57'S 115°48'E	09-Feb-11		Not a plant feeder	?
43	*Stenotaphrum secundatum*	Matilda	Shenton Park	WA	31°57'S 115°48'E	09-Feb-11		-	-
44	*Pennisetum clandestinum*	Common (seeding)	Fremantle	WA	32°03'S 115°45'E	09-Feb-11		-	-
45	*Cynodon dactylon*		Shenton Park	WA	31°57'S 115°48'E	09-Feb-11		-	-
46	*Stenotaphrum secundatum*	King's Pride	Shenton Park	WA	31°57'S 115°48'E	09-Feb-11		-	-

Sample #	Host Species	Variety	Location	State	Latitude, Longitude	Collection Date	Damage Symptoms	Mites Present	
								Family/Suborder	**Genus**
47	*Cynodon dactylon*		North Perth	WA	31°56'S 115°51'E	09-Feb-11		-	-
48	*Stenotaphrum secundatum*	Sir Walter	Shenton Park	WA	31°57'S 115°48'E	09-Feb-11		Cryptostigmata	1 x oribatid mite (detritus feeder)
49	*Stenotaphrum secundatum*	Sapphire	Shenton Park	WA	31°57'S 115°48'E	09-Feb-11		-	-
50	*Stenotaphrum secundatum*	Palmetto	Shenton Park	WA	31°57'S 115°48'E	09-Feb-11		Acaridae	Fungal feeder
51	*Stenotaphrum secundatum*	Sir James	Shenton Park	WA	31°57'S 115°48'E	09-Feb-11		-	-
52	*Pennisetum clandestinum*	Common (seeding)	Shenton Park	WA	31°57'S 115°48'E	09-Feb-11		Tenuipalpidae Acaridae Cryptostigmata	*Dolichotetranychus* (nymphs only) Orbatid mite
53	*Pennisetum clandestinum*	Common (seeding)	Swan Valley (Caversham)	WA	31°52'S 115°59'E	10-Feb-11		-	-
54	*Cynodon dactylon*		Swan Valley (Caversham)	WA	31°52'S 115°59'E	10-Feb-11		Tetranychidae	Not *Oligonychus* sp (very small for a tetranychid)
55	*Cynodon dactylon*		Swan Valley (The Vines)	WA	31°46'S 116°00'E	10-Feb-11		Eriophyidae	*Aceria*
56	*Pennisetum clandestinum*	Common (seeding)	Swan Valley (Caversham)	WA	31°52'S 115°59'E	10-Feb-11		Tenuipalpidae	*Dolichotetranychus* (nymphs only)
57	*Cynodon dactylon*	Conquest	Pakenham	VIC	38°07'S 145°28'E	21-Feb-11		Acaridae	Probably *Tyrophagus* (fungal feeder)
58	*Zoysia japonica*	Empire	Rochedale	QLD	27°34'S 153°09'E	25-Feb-11		-	-
59	*Cynodon dactylon*	Wintergreen	Rochedale	QLD	27°34'S 153°09'E	25-Feb-11	Pinetree-like growths in patches of weak grass growth	Tenuipalpidae	*Dolichotetranychus*
60	*Zoysia matrella*	Mixed varieties	Rochedale	QLD	27°34'S 153°09'E	25-Feb-11	Witch's brooming	-	-
61	*Pennisetum clandestinum*	Oakridge	Rochedale	QLD	27°34'S 153°09'E	25-Feb-11	None apparent	-	-

Sample #	Host Species	Variety	Location	State	Latitude, Longitude	Collection Date	Damage Symptoms	Mites Present	
								Family/Suborder	**Genus**
62	*Cynodon dactylon X transvaalensis*	Experimental lines	Merrimac	QLD	28°02'S 153°23'E	23-Mar-11	Witch's brooming	-	-
63	*Cynodon dactylon*	Common	Merrimac	QLD	28°02'S 153°23'E	23-Mar-11	Witch's brooming; weak growth patches	Cryptostigmata	Undetermined oribatid mite (fungal feeder)
64	*Cynodon dactylon*	UQ Experimental	Gleneagle	QLD	27°55'S 152°57'E	23-Mar-11	Witch's brooming; stolons poorly rooted down	-	-
65	*Stenotaphrum secundatum*	Sir Walter	Gleneagle	QLD	27°55'S 152°57'E	23-Mar-11	Crab-like growth (stolons not rooted down); some witch's brooming	-	-
66	*Cynodon dactylon*	Legend	Gleneagle	QLD	27°55'S 152°57'E	23-Mar-11	Some witch's brooming	-	-
67	*Cynodon dactylon* (Sample 1)	Common	Murarrie	QLD	27°28'S 153°07'E	28-Mar-11	Pinetree-like growths in patches of weak grass growth	Tenuipalpidae	*Dolichotetranychus*
68	*Pennisetum clandestinum* (Sample 1)	Common (seeding)	Murarrie	QLD	27°28'S 153°07'E	28-Mar-11	Proliferation of multiple growths; individual shoot tips clubbed (swollen, constricted)	Tenuipalpidae	*Dolichotetranychus*
69	*Sporobolus virginicus* (Sample 1)	Marine couch	Murarrie	QLD	27°28'S 153°07'E	28-Mar-11	Distorted proliferation of multiple growths (witches brooming)	Eriophyidae Tetranychidae Stigmaeidae (possibly)	*Acunda* *Monoceronychus* Genus unknown
70	*Cynodon dactylon* (Sample 2)	Common	Murarrie	QLD	27°28'S 153°07'E	28-Mar-11	Pinetree-like growths in patches of poor grass growth	Tenuipalpidae	*Dolichotetranychus*
71	*Pennisetum clandestinum* (Sample 2)	Common (seeding)	Murarrie	QLD	27°28'S 153°07'E	28-Mar-11	Proliferation of multiple growths; individual shoot tips clubbed (swollen, constricted)	Tenuipalpidae	*Dolichotetranychus*
72	*Sporobolus virginicus* (Sample 2)	Marine couch	Murarrie	QLD	27°28'S 153°07'E	28-Mar-11	Individual shoot tips clubbed (swollen like galls, constricted vertical growth	Eriophyidae Tetranychidae	*Aceria* (2 spp.) *Acunda* *Monoceronychus*
73	*Paspalum vaginatum*	Sea Spray	Murarrie	QLD	27°28'S 153°07'E	28-Mar-11	Stolons not rooted down & with shortened internodes	-	-
74	*Digitaria didactyla*	Common	Murarrie	QLD	27°28'S, 153°07'E	28-Mar-11	None; close proximity to other affected grasses	-	-

Sample #	Host Species	Variety	Location	State	Latitude, Longitude	Collection Date	Damage Symptoms	Mites Present	
								Family/Suborder	Genus
75	*Cynodon dactylon* (Sample 1)	Discovery	Boyland	QLD	27°56'S 153°08'E	06-Apr-11	Severe witch's brooming; some swollen constricted growths with very short leaf blades	Eriophyidae	*Aceria* (near *cynodoniensis)*
76	*Cynodon dactylon* *(*Sample 2)	Discovery	Boyland	QLD	27°56'S 153°07'E	06-Apr-11	Severe witch's brooming; some swollen constricted growths with very short leaf blades	-	-
-	*Cynodon dactylon*	Wintergreen	Cleveland	QLD	27°31'S 153°15'E	16-Feb-11		N/A	N/A
-	*Cynodon dactylon*	Wintergreen	Cleveland	QLD	27°31'S 153°15'E	16-Feb-11		N/A	N/A
77	*Pennisetum clandestinum*	Oakridge	Rochedale	QLD	27°34'S 153°09'E	12-Apr-11	Proliferation of multiple growths; individual shoot tips clubbed (swollen, constricted)	N/A	N/A
78	*Zoysia japonica*	Empire	Rochedale	QLD	27°34'S 153°09'E	12-Apr-11	Stolons poorly rooted; witch's brooming	Cryptostigmata Acaridae Tarsonemidae	Oribatid mite (undetermined) 1 X probably *Tyrophagus* (detritus feeder) Nymphs only (probably fungal feeder - further ID impossible)
79	*Cynodon dactylon*	UQ Experimental	Gatton	QLD	27°32'S 152°20'E	13-Apr-11	Stolons poorly rooted; witch's brooming	-	-
80	*Pennisetum clandestinum* (Sample 1)	Common (seeding)	Toowoomba	QLD	27°35'S 151°58'E	13-Apr-11	Proliferation of multiple growths; individual shoot tips clubbed (swollen, constricted); some distorted stolons with shortened internodes, proliferation of side shoots & no roots	-	-
81	*Pennisetum clandestinum* (Sample 2)	Common (seeding)	Toowoomba	QLD	27°35'S 151°58'E	13-Apr-11	Proliferation of multiple growths; individual shoot tips clubbed (swollen, constricted); some distorted stolons with shortened internodes, proliferation of side shoots & no roots	-	-

Sample #	Host Species	Variety	Location	State	Latitude, Longitude	Collection Date	Damage Symptoms	Mites Present	
								Family/Suborder	Genus
82	*Pennisetum clandestinum* (Sample 3)	Common (seeding)	Toowoomba	QLD	27°35'S 151°58'E	13-Apr-11	Proliferation of multiple growths; individual shoot tips clubbed (swollen, constricted)	Tarsonemidae	Females/nymphs only - probably fungal feeder (further ID not possible as need males)
83	*Stenotaphrum secundatum*	Palmetto	Chambers Flat	QLD	27°46'S 153°05'E	15-Apr-11	Crab-like growth (stolons not rooted down); some witch's brooming	-	-
84	*Zoysia matrella*	Shadetuff	Chambers Flat	QLD	27°46'S 153°05'E	15-Apr-11	Stolons poorly rooted; witch's brooming	Eriophyidae?	Possibly 1 eriophyoid seen; couldn't retrieve
85	*Cynodon dactylon*	Common	Murarrie	QLD	27°28'S 153°07'E	18-Apr-11	Pinetree-like growths in a patch of weak grass growth	Tenuipalpidae	*Dolichotetranychus*
86	*Zoysia japonica X matrella*	ZT-11	Booral	QLD	25°21'S 152°51'E	18-Apr-11	Stolons not rooted down; witch's brooming	-	-
87	*Zoysia japonica*	Z-3	Booral	QLD	25°21'S 152°51'E	18-Apr-11	Stolons not rooted down; witch's brooming	Acaridae	Probably *Tyrophagus* (fungal feeder)
88	*Stenotaphrum secundatum*	Sir Walter	Booral	QLD	25°21'S 152°51'E	18-Apr-11	Crab-like growth (stolons not rooted down); witch's brooming & shortening of stolon internodes	N/A	N/A
89	*Cynodon dactylon*	Oz Tuff	Booral	QLD	25°20'S 152°51'E	18-Apr-11	Slender pinetree-like growths (shortened internodes but not much thickening below apex); some witch's brooming	-	-
90	*Cynodon dactylon*	Wintergreen	Booral	QLD	25°21'S 152°51'E	18-Apr-11	Pinetree-like growths in patches of weak grass growth	Tenuipalpidae	*Dolichotetranychus*
91	*Zoysia matrella*	Shadetuff	Booral	QLD	25°21'S 152°51'E	18-Apr-11	Stolons not rooted down; witch's brooming	-	-
92	*Stenotaphrum secundatum*	Matilda	Booral	QLD	25°21'S 152°51'E	18-Apr-11	Crab-like growth (stolons not rooted down); witch's brooming & some shortening of stolon internodes	-	-
93	*Zoysia matrella*	Shadetuff	Tinbeerwah	QLD	26°25'S 152°58'E	18-Apr-11		Eriophyidae	*Aceria*

Sample #	Host Species	Variety	Location	State	Latitude, Longitude	Collection Date	Damage Symptoms	Mites Present	
								Family/Suborder	Genus
94	*Stenotaphrum secundatum*	Sapphire	Windsor	NSW	33°35'S 150°48'E	12-Apr-11		-	-
95	*Cynodon dactylon X transvaalensis*	Santa Ana	Agnes Banks	NSW	33°36'S 150°43'E	20-Apr-11		-	-
96	*Stenotaphrum secundatum*	Kings Pride	Agnes Banks	NSW	33°36'S 150°43'E	20-Apr-11		-	-
97	*Cynodon dactylon*		Kellyville	NSW	33°43'S 150°58'E	15-Apr-11		-	-
98	*Cynodon dactylon*	Conquest	Seaford	VIC	38°07'S 145°08'E	27-Apr-11		N/A	N/A
99	*Cynodon dactylon*	Riley's Super Sport	Frankston South	VIC	38°10'S 145°06'E	28-Apr-11		Eriophyidae	*Aceria* (near *cynodoniensis)*
100	*Cynodon dactylon*	Grand Prix	Carnlea	VIC	37°45'S 144°47'E	27-Apr-11		-	-
101	*Cynodon dactylon*	Unknown	Keilor Park	VIC	37°43'S 144°51'E	27-Apr-11		N/A	N/A
102	*Pennisetum clandestinum*	Common (seeding)	Sandringham	VIC	37°57'S 145°01'E	27-Apr-11	Sprayed with abamectin early to mid-April; symptoms still obvious	-	-
103	*Pennisetum clandestinum*	Common (seeding)	Seaford	VIC	38°07'S 145°08'E	27-Apr-11		Acaridae	Probably *Tyrophagus* (detritus/fungal feeders)
104	*Pennisetum clandestinum*	Common (seeding)	Montmorency	VIC	37°43'S 145°07'E	27-Apr-11		-	-
105	*Pennisetum clandestinum*	Common (seeding)	Wayville	SA	34°56'S 138°35'E	5-May-11		Acaridae	Probably *Tyrophagus* (detritus/fungal feeders)
106	*Pennisetum clandestinum*	Common (seeding)	Langhorne Creek	SA	35°18'S 139°01'E	5-May-11		-	-
107	*Cynodon dactylon* (Site 1)		Glenelg	SA	34°59'S 138°31'E	6-May-11		Tarsonemidae	1 X female ; require male specimens for further ID (possibly fungal feeder)
108	*Paspalum vaginatum* (Site 1)		Glenelg	SA	34°59'S 138°31'E	6-May-11		-	-

Sample #	Host Species	Variety	Location	State	Latitude, Longitude	Collection Date	Damage Symptoms	Mites Present	
								Family/Suborder	**Genus**
109	*Cynodon dactylon*	Windsor Green	Langhorne Creek	SA	35°18'S 139°01'E	5-May-11		-	-
110	*Paspalum vaginatum*		Glenelg	SA	34°59'S 138°31'E	6-May-11		-	-
111	*Pennisetum clandestinum* (Site 1)	Common (seeding)	Glenelg	SA	34°59'S 138°31'E	6-May-11		Acaridae	Probably *Tyrophagus* (detritus/fungal feeders)
112	*Cynodon dactylon*		Glenelg	SA	34°59'S 138°31'E	6-May-11		-	-
113	*Stenotaphrum secundatum*	Kings Pride	Langhorne Creek	SA	35°19'S 139°01'E	5-May-11		-	-
114	*Pennisetum clandestinum*	Common (seeding)	Unley	SA	34°57'S 138°36'E	5-May-11		Tarsonemidae	1 X female ; require male specimens for further ID (possibly fungal feeder)
115	*Cynodon dactylon*		Seaton	SA	34°54'S 138°30'E	6-May-11		Tenuipalpidae	*Dolichotetranychus*
116	*Pennisetum clandestinum*	Common (seeding)	Langhorne Creek	SA	35°19'S 139°01'E	5-May-11		-	-
117	*Cynodon dactylon X transvaalensis*	Santa Ana	Langhorne Creek	SA	35°18'S 139°01'E	5-May-11		Acaridae	Probably *Tyrophagus* (detritus/fungal feeders)

N/A Delivered sample unusable; not extracted.

Table 5. Categories of use for turf samples tested for mites. See Table 4 for collection site details for each sample.

Situation	Number of samples	Sample identification numbers
Turf farms	48	1, 2, 3, 8, 9, 10, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24, 25, 26, 57, 58, 59, 60, 61, 64, 65, 66, 75, 76, 77, 78, 83, 84, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 106, 109, 113, 116, 117
Other country sites	5	6, 53, 54, 55, 56
Sports facilities (e.g. sports fields, golf and tennis clubs, race tracks)	15	4, 5, 38, 39, 40, 41, 47, 62, 63, 100, 101, 103, 104, 105, 110
Urban open space (e.g. parks, roadsides) and domestic/business lawns	35	23, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 44, 67, 68, 69, 70, 71, 72, 73, 74, 80, 81, 82, 85, 97, 98, 99, 102, 107, 108, 111, 112, 114, 115
Research facilities	16	7, 11, 12, 13, 42, 43, 45, 46, 48, 49, 50, 51, 52, 79 (plus 2 samples not numbered)

Table 6. Summary of mite determinations in samples of 7 warm-season turfgrass taxa and one grass weed. Per cent mite-infested samples has been calculated for samples received in good condition.

Host Species	No. of Samples Received		No of Samples with Mites Extracted			% Infested with Phytophagous Mites[1]
	Total	Good Condition	Eriophyidae	Tenuipalpidae	Other Mites	
Cynodon spp.	45	31	7	8	8[2]	54.8
Digitaria didactyla	3	3	0	1	0	33.3
Digitaria sanguinalis	1	1	0	0	0	0.0
Paspalum vaginatum	4	4	0	0	1	0.0
Pennisetum clandestinum	28	18	0	9	4	50.0
Sporobolus virginicus	2	2	2	0	2	100.0
Stenotaphrum secundatum	16	12	0	0	4	0.0
Zoysia spp.	20	15	4	2	2	40.0

[1] (Eriophyidae + Tenuipalpidae)/No. Received in Good Condition

[2] Includes one undetermined tetranychid species (sample 54), which was assumed to be plant-feeding for subsequent calculations.

Zoysia samples showed an apparent predominance by *Aceria* species among the positive infestations identified, though *Dolichotetranychus* species were also significant and were found in samples from both northern and southern Queensland. Moreover, sampling from a variety experiment at Rochedale (QLD) led to only one positive extraction (*Dolichotetranychus*), though comparable symptoms were seen on the five other *Zoysia* genotypes sampled at the same site on the same day.

Sporobolus virginicus is an Australian native species from coastal habitats, but with a pan-tropical distribution worldwide. While used to a limited extent as a rehabilitation species in disturbed coastal areas, it also has some potential as a highly salt-tolerant turfgrass, with one recently registered cultivar (Roche 2010). Significantly perhaps, infestation by *Dolichotetranychus* in the mixed sward sampled at Murarrie (QLD) did not extend into *S. virginicus*, which instead had its own distinctive suite of mite species: two *Aceria*, one *Acunda* (Eriophyidae) and a *Monoceronychus* (Tetranychidae) species (D.K. Knihinicki, unpublished observations 2011).

Subtle differences in the symptoms seen are perhaps indicative of the plant-feeding mite species extracted, though we would hesitate to say without further experience and data that such differences are diagnostic of the mite species involved. In *Cynodon*, witch's brooming and poor stolon root development were typical of infestations by *Aceria* species (Plate 11). At the same time, individual growths could show shortening and thickening to give a 'pinetree' effect. *Dolichotetranychus* species, on the other hand, produced a characteristic thinning and weakening of the stand, usually concentrated in patches, without witch's brooming but with slightly more thickened pinetree-like growths (Plate 12). They can also be found persisting in some quite old pinetree-like growths, though not as prevalent as in younger growths.

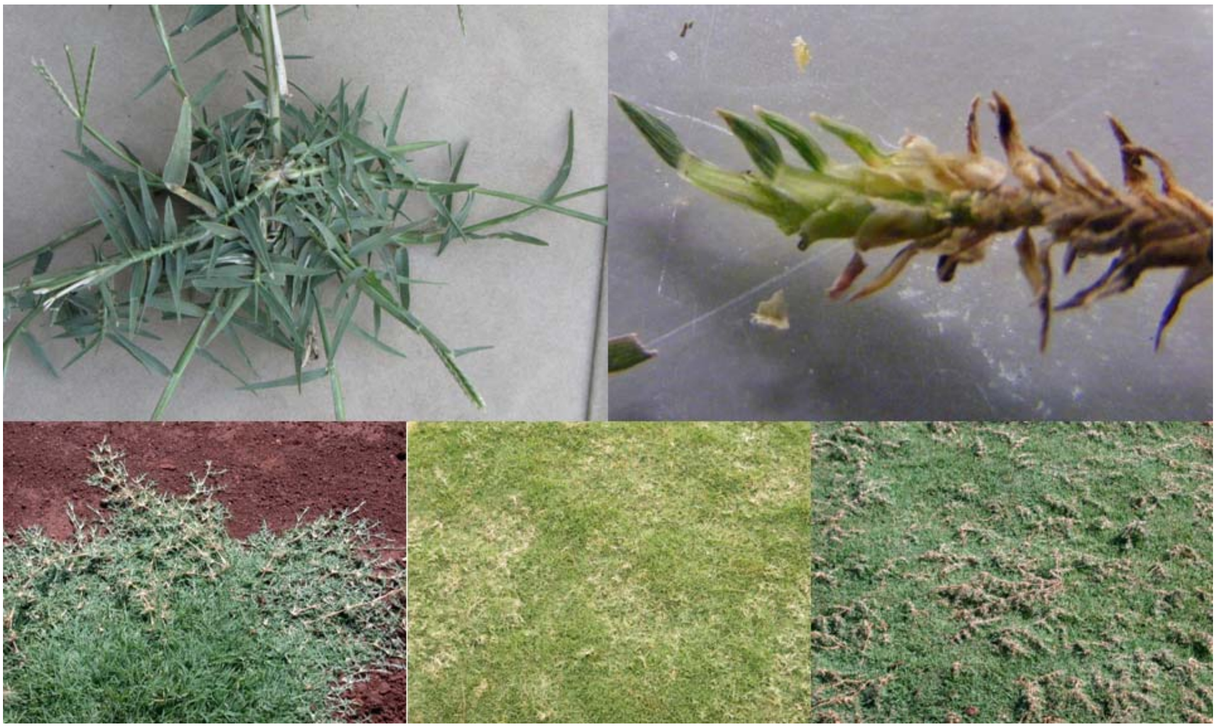

Plate 11. Visual symptoms associated with infestations of *Aceria* species on *Cynodon* spp.: close-up photographs of witch's broom (*top left*) and shortened thickened individual shoot (*top right*); swards showing witch's brooming (*bottom left and centre*) together with poor stolon rooting (*bottom right*).

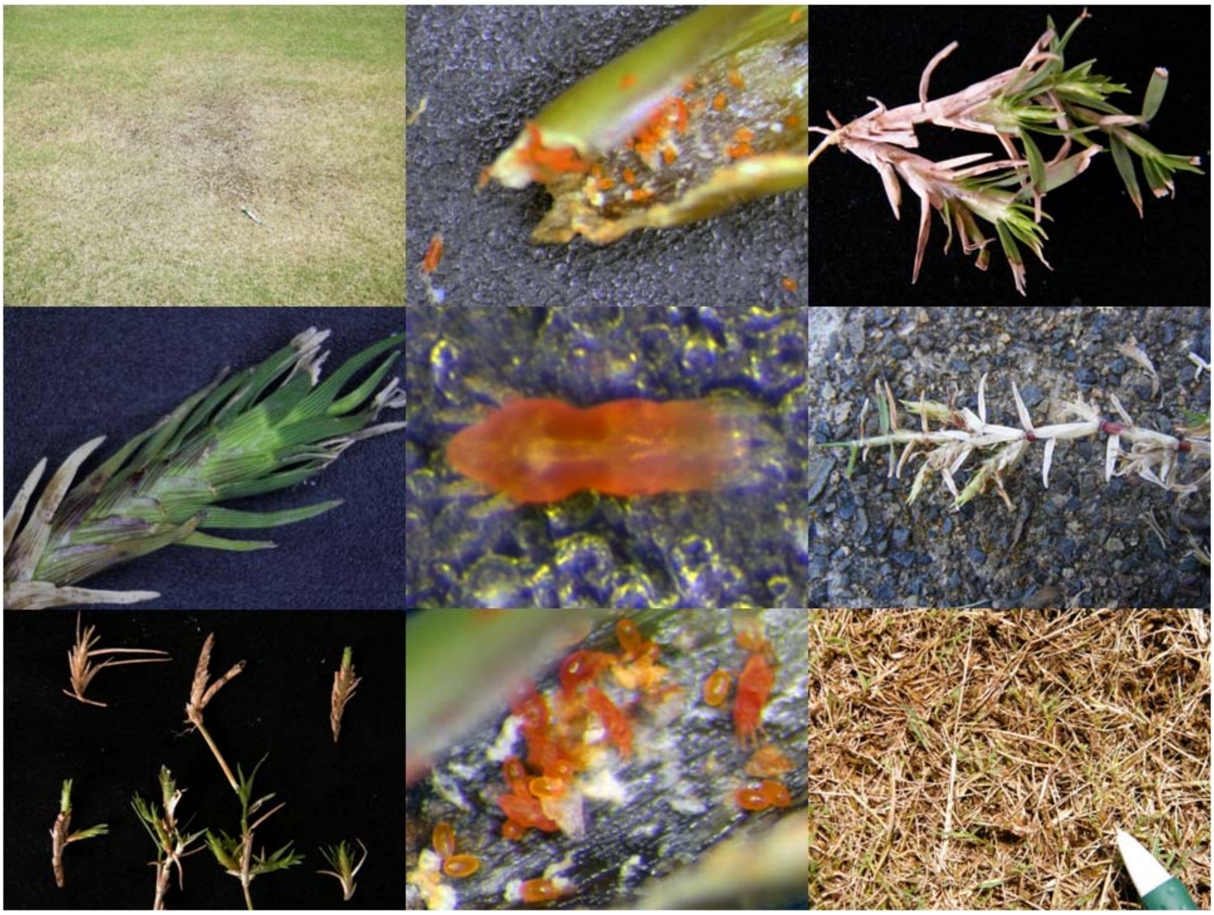

Plate 12. Visual symptoms associated with infestations of *Dolichotetranychus* species on *Cynodon* spp.: characteristic thinning and weakening of the stand (*top left*) and development of pinetree-like growths without witch's brooming (*bottom right*); close-up photographs of pinetree-like growth development (*left centre and bottom, right top and centre*); and *Dolichotetranychus* species ± eggs (*centre, top to bottom*).

In *Zoysia*, strong witch's brooming and poor stolon rooting appear to be more typical of *Dolichotetranychus*, while *Aceria* infestations showed more limited 'rosetting' at the stolon nodes (Plates 13 and 14).

Plate 13. Visual symptoms associated with infestations of *Aceria* species on *Zoysia* spp.

Plate 13. Visual symptoms associated with infestations of *Dolichotetranychus* species on *Zoysia* spp.

A variety of symptoms were associated with *Dolichotetranychus* infestations on kikuyu grass (Plate 14). Spaced plants and isolated stolons showed poor rooting down, shortening of the internodes, and a proliferation of side shoots. In a dense stand without the need to spread by stolons, the tillers showed a proliferation of multiple growths, which individually showed shortening and thickening to give a 'clubbed' appearance.

Plate 14. Visual symptoms associated with infestations of *Dolichotetranychus* species on *Pennisetum clandestinum*: spaced plants showing poor root development, shortening of the internodes, and a proliferation of side shoots (*left top and bottom*); tiller proliferation giving 'clubbed' growths (*right top and bottom*); and old distorted growths no longer harbouring any phytophagous mites (*centre top and bottom*).

Insects were also found in 5 of the 119 samples (data not presented in Table 4). These included thrips (samples 44, 64), ground-dwelling Collembola (48, 113), and a caterpillar (48). While these were not surprising and of no real consequence, the possible presence of suspected ground pearl (Margarodidae) nymphs in samples 49 and 73 is of some concern.

DISCUSSION

Diagnosis of Mite Infestation

In commercial practice, the diagnosis of a mite infestation must, of necessity, be made on the basis of symptoms seen on the plant host. For this reason in the preceding section, we provided detailed illustrated descriptions of the symptoms seen on different turfgrass hosts and their association with the different groups of mites identified in our survey as the basis of a guide to turf producers and managers. The actual mites themselves, however, are very much a case of where and when you find them. It was not possible, and it is not possible, to associate specific mites with symptoms of mite infestation in each and every case.

Sampling Practices

As suggested by Monfreda *et al.* (2010), the symptoms of mite infestation can prove deceptive when taking a sample of material to check for the presence of mites. Rather than being in the older distorted growths, the mite populations (particularly the eriophyoids which appeared to be faster moving than the tenuipalpids) might have moved to fresher, younger growth perhaps showing little or no visible damage as yet. Of the 64 samples of *Cynodon*, kikuyu and *Zoysia* received for processing in good condition, plant-feeding mites alone were extracted from 29 samples (45.3%), fungal and detritus feeding mites from 10 samples (15.6%), and both groups together from a further 3 samples (4.7%); no mites were extracted from the remaining 22 samples (34.4%). The number of samples with fungal and detritus feeding mites present does suggest that relatively old material was sampled in at least 20% of cases. In this context, the contrast between the Canberra (ACT) and Toowoomba (QLD) samples also pertinent: the former consisted of occasional distorted stolons here and there but yielded mites, while the latter collections were taken from areas showing severe symptoms but yielded no mites.

Over the year, populations of mites, particularly eriophyoids, may come and go as Butler (1963) found in his studies of *Aceria cynodoniensis* in Arizona, though the slower-moving tenuipalpids do seem to be less ephemeral and fickle to find consistently in the field. As an example of temporal variation in our survey, re-sampling at Gordonvale (QLD) in November 2010 (samples 14, 15) failed to find phytophagous mites in contrast to the earlier sampling in August 2010. Spatial variation also occurs as demonstrated by sampling of *C. dactylon* cv. Discovery at Boyland (QLD): sample 75 taken from a tub planting was heavily infested by an *Aceria* species; but sample 76, collected on the same day from a field plot on the same property and showing severe symptoms of mite damage across the whole area, failed to yield any mites at all.

In the present survey, we had to work within the limitation of posting fresh material to Orange for processing. The fact that 27.7% of samples arrived in poor condition, including 5% that were completely unusable, warrants comment on the collection, storage and dispatch of samples to improve this aspect in any future work. Firstly, every effort needs to be taken to avoid any soil contamination, even a very small amount, when taking the sample; finely divided decomposed organic matter can also cause problems in locating mites after extraction. Samples need to be kept fresh and cool after sampling (preferably in the crisper of the refrigerator), and then dispatched for processing as soon as possible. The temptation to hold samples over to add to the posted consignment no doubt led to some of the deterioration of samples towards the end of our study; in practical terms, samples should be posted for final processing no later than the beginning of the next week after collection. The Booral (QLD) samples were collected on a rainy day, and it seems that the excessive moisture present contributed to their more rapid deterioration prior to arrival in Orange. Samples with excessive moisture also seem to deteriorate more rapidly even under refrigeration. Finally, delays in transit, even on occasions with Express Post, increase the likelihood of deterioration before delivery; for obvious reasons, the slower general post should be avoided.

Grass-Feeding Mites Identified

Although full identification of the plant-feeding mites found is beyond the resources and time available in the present project, it is important that this be completed in the future, perhaps in a follow-up project. This is the only way we will know for sure whether we have some of the same mite species that affect turfgrasses in other parts of the world and perhaps some uniquely Australian species as well.

Tenuipalpidae

At the start of our survey, the expectation was that we would be dealing mainly with eriophyoid mites. In fact, we found that the tenuipalpid *Dolichotetranychus* species (singular or plural) was as important, if not more important, than the eriophyoids on Australian turfgrasses. While the probable species (or primary species) involved, *Dolichotetranychus australianus*, was described from an infestation on *Cynodon dactylon* in southern Queensland around 70 years ago, it has gone almost unrecognised on turfgrasses since then. While Smiley and Gerson (1995) indicated that *D. australianus* had not been recorded outside of Queensland, we found *Dolichotetranychus* species from Gordonvale (QLD) and Perth (WA), with intervening collections from NSW, ACT, VIC and SA, as well as from other parts of QLD. It is not clear whether this represents a single species or more than the one species, although the collections from SA were notable for their strong red colour compared with the more orange-red colouring seen elsewhere. A detailed taxonomic study would further reveal the identity of the species involved.

Dolichotetranychus mites infest *Cynodon* and *Zoysia* species, and were the only mite group recorded on kikuyu but did not extend onto *Sporobolus virginicus* in a mixed sward. There was also a single collection of *Dolichotetranychus* from blue couch (*Digitaria didactyla*), though further sampling, preferably during a dry spring, will be necessary to determine if this is the only mite species affecting blue couch. The *Dolichotetranychus* mites show some interesting differences from the eriophyoid mites seen on *Cynodon* and *Zoysia*. Firstly, they are slow-moving and so infestations on *Cynodon* typically appear as concentrated patches apparently resulting from crowding rather than dispersal of the mites. *Dolichotetranychus* also appear to remain active even in very cold weather, and have been observed as still mobile in samples of kikuyu from Griffith (NSW) taken in mid-winter after 8 days of successive frosts down to -7°C (P. McMaugh, unpublished observations 2010) and also tend to remain active on kikuyu through the winter in Melbourne (D. Nickson, unpublished observations 2009). On racetracks in Sydney, bleaching of kikuyu in large patches has been linked to the presence of *Dolichotetranychus* (P. McMaugh, unpublished observation 2010). These grass-feeding mites may also have hitherto unsuspected implications for Australian pastoralists as one of the infested samples (#56) came from a heavily-grazed pasture.

Despite the conventional wisdom that mites thrive in hot dry weather and decline during wet periods, microscopic examination of dissected samples collected at Rochedale (QLD) approximately a week after the Brisbane floods in January 2011 still showed some adult *Dolichotetranychus* and a lot of eggs present. A second microscopic examination 5 weeks later in late February 2011 showed dense populations of both mites and eggs (see Plate 12). Anecdotal evidence on turf farms with *Cynodon* infested with *Dolichotetranychus* is that the mites are extremely difficult to control, even with regular miticide applications, perhaps because of difficulty in penetrating the protective pinetree-like growths where the mites shelter from predators and feed under the leaf sheaths. This perhaps parallels Elder's (1988) singularly unsuccessful experience in trialling 12 different pesticides to control the closely related *D. floridanus* on pineapples without positive results.

Eriophyidae

Eriophyoid mites were recorded on both *Cynodon* and *Zoysia* species, although until detailed identifications of specimens have been completed it is not clear whether one, two, or more species of *Aceria* are involved. In the case of *Cynodon* species and assuming that only one mite species is involved, the most probable one as noted in Table 4 is *Aceria cynodoniensis*, which has previously been reported from Australia (Gibson 1967; Halliday 1998). We have not seen symptoms on *Cynodon* species in Australia typical of the second bermudagrass mite, *Aceria cynodonis*, reported from the USA (Wilson 1959; Keifer *et al*. 1982), nor has it been recorded in Australia (Halliday 1998).

Similarly, we have not seen the 'buggy-whip', leaf chlorosis and marginal roll symptoms reportedly typical of *Aceria zoysiae* on *Zoysia* species in the USA (Plate 15; see also Plate 10), nor has this mite species been recorded in Australia (Halliday 1998). Given the very host-specific nature of most eriophyoid mites, it is interesting to speculate on the possible source of the *Aceria* species recorded on 4 (probably 5) samples of *Zoysia* from northern and southern Queensland (1, 2, 23, 93, 84?). Since *A. cynodoniensis* has never been recorded on *Zoysia*, it is possible that a native *Aceria* species from a native grass may be involved; based on the presence of *Aceria zoysima* on *Zoysia minima* in New Zealand (Manson 1989), the most likely native grass host would be *Zoysia macrantha*.

Plate 15. Visual symptoms associated with *Aceria zoysiae* infestation of *Zoysia* species in USA. (*Photographs: Dr Aaron Patton*).

Subsequently, symptoms typical of the zoysia mite (*A. zoysiae*) were observed on *Zoysia japonica* near Beijing (PR China) in July 2011 (N.R. Walker and D.S. Loch, unpublished observation 2011). These were present in scattered small patches of distorted unthrifty growth and showed the characteristic 'buggy-whipping' effect on the emerging leaves (Plate 16).

Plate 16. Symptoms typical of zoysia mite infestation on *Zoysia japonica* near Beijing (PR China).

The separation of an *Abacarus* species (D.K. Knihinicki, unpublished observation 2011) from a single WA *C. dactylon* collection (36) is an interesting new development, since that genus includes two significant economic pests, *A. hystrix* (cereal rust mite) and *A. sacchari* (sugarcane rust mite). *A. hystrix* occurs in Australia (Halliday 1998) and has a wider host range than most other eriophyoid mites, though it may be a complex species consisting of specialised races for different hosts (Skoracka and Kuczyński 2006). It is also a vector for at least two plant virus diseases (Lindquist *et al.* 1996).

Other Grasses

The two samples of the native *Sporobolus virginicus* highlight the unsuspected complexity of mite infestation that may exist in some of our other native grass species. Four species of mites, possibly all previously undescribed, were extracted: *Acunda*, *Monoceronychus* and two *Aceria* species (Table 4). No *Aceria* specimens were recovered from the four *Cynodon* and kikuyu samples (67, 68, 70, 71) taken concurrently from the mixed sward at Murarrie (QLD), suggesting that these may be new species host-specific to *S. virgincus*. The second eriophyoid genus, *Acunda*, was established by Keifer (1965) to accommodate *Acunda plectilis* found in the terminal rolled leaves of *Distichlis spicata* in California, but has not previously been recorded in Australia (Halliday 1998; D.K. Knihinicki unpublished observations 2011). Similarly, *Monoceronychus* – a tetranychid genus of grass-infesting mites – has not previously been reported in Australia (Halliday 1998; D.K. Knihinicki unpublished observations 2011). From a comparison of the two samples (69, 72), it also appears that the inclusion of the *Aceria* species changes the symptoms from witches brooming of the upright tillers with relatively unswollen tips (#69) to having swollen 'clubbed' tips on the tillers (Plate 17), though this would need to be confirmed on additional samples preferable from new collection sites. Similar 'clubbing' of the tiller tips (but not as swollen as in this case with *S. virginicus*) have previously been seen on the native *Distichlis distichophylla* in southern Australia (D.S. Loch, unpublished observations 2002), and should also be checked for the possible presence of phytophagous mites.

Plate 17. Visual symptoms associated with mite infestations on *Sporobolus virginicus*: sample 1 (#69) showing witch's brooming alone (*left*); sample 2 (#72) showing swollen mite-infested galls giving distinctive 'clubbed' ends to the tillers (*centre, right*).

Despite showing distinctive symptoms suggestive of mite infestation (crab-like stolon growth with poor rooting, shortened internodes and witch's brooming), no plant-feeding mites were extracted from any of the 12 samples of *Stenotaphrum secundatum* received in good condition (Tables 4 and 5). Mites have been reported on this species in USA by Wolfenbarger (1953) and recently by J.A. Reinert (pers. comm. 2009). In one-third of our *Stenotaphrum* samples, predatory and other mites were recovered, so this may be a case of not sampling the right material or of having taken samples at the wrong time. In two cases (83, 88) which did not arrive in good condition, dissection prior to submission revealed the presence of some mite-like organisms. Alternatively, there may be organisms other than mites that are causing the symptoms seen; and we cannot rule out possibility that we may be mistaking normal growth patterns for the species as mite damage. Further sampling of buffalo grass, particularly during the drier spring and early summer months, and taking care in selecting the collected material, is necessary to resolve these outstanding issues.

It's a 'Zoo' Out There: Future Studies Needed to Understand the Biology, Ecology and Population Dynamics of Turfgrass-Feeding Mites

Mites are ecology in action at a micro-scale. While we were targeting the plant-feeding mites that cause economic damage to the host turfgrass species, we also found predatory mites, as well as fungal and detritus feeders and even some insects, in the samples analysed. With our present state of knowledge, we can only guess at the complexities of the relationships and interactions in these hidden communities that cannot be seen at our macro level. Yet it is only with a better knowledge of these relationships and interactions, together with the biology, ecology and population dynamics of the key species, that we can hope to develop better methods of controlling the phytophagous mites that damage turfgrasses, or at least reducing their populations to acceptable levels where it is not necessary to reach for a can of miticide quite as often.

Surprisingly, our results showed no overlap between tenuipalpid and eriophyoid mite populations in the same turfgrass sample. Contrast this with Sayed's (1946) initial discovery of *Aceria cynodoniensis* mixed with *Dolichotetranychus* (probably *D. australianus*) on *Cynodon dactylon* in Egypt. Similarly, Abou-Awad and Nasr (1983) reported combined infestations of the two eriophyoid species, *Abacarus cynodonis* and *Eriophyes niloticus*, on *Cynodon dactylon* in the Sinai Peninsula (see also Review of Literature). It was only on the two samples of native *Sporobolus virginicus* (69, 72) that we found mixed populations of plant-feeding mites. The complexity of mite populations in relation to their spatial (and temporal) distribution is emphasised by the fact that, although these 2 samples were taken no more than about 10 m apart, they showed completely different sets of mite-damage symptoms probably as a result of their differences in mite species composition.

The study by Ozman and Goolsby (2005) on the eriophyoid mite *Floracarus perrepae* host-specific on *Lygodium microphyllum* (climbing fern) provides a good example of the level of background information that needs to be generated on each of the plant-feeding mites that infest the different turfgrasses surveyed. This includes population dynamics through the year identifying any peaks or troughs in numbers and the factors (temperature, moisture) that influence this, ratios of females to males, times for each stage of development for each stage from eggs through to adulthood and death; fecundity of females. Predatory mites and any acaropathogenic fungi also need to be identified for the development of management strategies to maximise their impact on phytophagous mite populations.

Anecdotally, turf mite populations and their impact on turf have increased over the past couple of decades, possibly because some of the pesticides used have a negative impact on the as yet unknown predators as described by May (1949) in relation to fruit trees. Elder (1988), for example, found that both chloripyrifos and dimethoate had negative effects on populations of a predatory mite which naturally controlled *Dolichotetranychus floridanus* (pineapple flat mite). Some turf producers believe that they are seeing less mite damage since using chlorantraniliprole (Acelepryn®) for insect control, possibly because it may be softer on the beneficial predators of the turf mites; otherwise, chlorantraniliprole has little or no direct effect on those mite populations.

Despite the fact that many species are recognised plant pests, the Tenuipalpidae have long been neglected as a family of economic importance warranting greater research (Jeppson *et al.* 1975; Gerson 2008). In the context of turf and the Australian turf industry, the tenuipalpid *Dolichotetranychus australianus* could well be said to be the forgotten mite species, all of the previous focus being on eriophyoid mites. In terms of the damage they cause, *Dolichotetranychus* species are at least as important as the eriophyoids; and since so little is known about their life cycle, biology and ecology, we feel that the *Dolichotetranychus* species warrant priority in any future work of this kind. First, however, the identification of the tenuipalpid and eriophyoid specimens stored following completion of our survey need to be confirmed or described (if new) down to species level.

Plant-based factors (e.g. fibre and nutrient levels, silica) that could provide resistance or predispose a cultivar to mite attack also need to be investigated and identified. Varieties do differ in their tolerance of, or susceptibility to, mites, though the order of resistance can inexplicably change from time to time as shown by comparison of the various US studies done on this topic. Anecdotally and based on observations over many years, the *Cynodon* cultivars AgriDark and Discovery appear to be two of the most susceptible varieties seen, consistently showing symptoms of severe mite damage while another (different) cultivar in the adjacent plot may show little of no effect of mites.

Conclusions

During our survey, symptoms of mite damage were seen on turf farms, in parks and on other turf venues across Australia in all of the 5 states and one territory sampled. Plant-feeding mites were extracted from 50% of samples taken from *Cynodon, Zoysia* and kikuyu. Mite damage is widespread and its economic impact should be of major concern to all turf producers and turf managers. Mite damage levels vary from mild to extreme, and future consideration needs to be given to defining the economic threshold of damage at which control treatments should begin.

For the turf farmer, production fields take longer to grow in, lengthening the turn-around period from the harvest of one crop to the harvest of the next crop. Poor rooting ability is a common feature of the different mite infestations, which then leads to breakage of rolls and greater wastage during harvest. In general, the distorted growths typical of mite infestation tend to be more obvious where nutrition is low, hence the use of N fertiliser and additional irrigation to compensate to some extent, thereby masking the damage done by mites; however, this adds to costs of production, as does the application of miticides to control mite infestations. In the case of kikuyu, most turf growers tend to keep N levels very high, even to the point of over-fertilising, to mask the damage being done by mites, but this also increases the ecological risk of losing excessive amounts of N through leaching and in run-off.

As with the treatment of any problem, the starting point is a correct diagnosis of the primary cause. Erroneous diagnoses, however, come in many forms. For example, a recent outbreak of aphids on a turf farm was diagnosed as mites by a commercial sales representative, leading to the use of the wrong pesticide. Ignorance regarding the identity of large numbers of predatory mites found on two turf farms has recently led to spraying by the farm managers to control what should have been a natural part of the solution, not their actual (undiagnosed) problem (Appendix 2). In Perth, some parks managers have invested in water crystals to overcome the perceived drought susceptibility of their turf, while overlooking the mite damage leading to droughting of that same turf. Mites transmit fungal and virus diseases and can also weaken the infested grass, pre-disposing it to secondary infections. Couchgrass summer decline has been diagnosed as being caused by a suite of ectotrophic root-infecting (ERI) fungi (Stirling and Stirling 2006); however, careful examination of photographs and close inspection of hybrid *Cynodon* in trial plots at Lakelands Golf Club and on other golf facilities in Queensland indicates that mite damage could also have been present (P. McMaugh, unpublished observations 2010). Further work is therefore warranted to assess critically the role that mites may play in couchgrass summer decline, perhaps as the primary cause by weakening the plant and thereby facilitating subsequent fungal infection. Anecdotal reports from experienced turf managers in northern and southern Queensland suggest that some turf diseases do seem to improve after spraying to control mites.

Awareness is the key to more accurate and timely identification of mite infestations in turf, followed by better informed decision-making. This was the underlying objective of this project, which simply aimed to find out what mite populations exist in the field and their relevance to damage levels on turf across Australia. Through our survey, we now have the necessary material to create better awareness of the problems caused by mites on turf in this country. We have answered some very basic questions such as:

- "Do we have mites in turf?" – Yes,
- "Do they cause economic loss?" – Yes,
- "What mite is it?" – We have two major groups of non-webbing mites, not just the eriophyoid group as previously thought.

However, we still do not have answers to a lot of other questions such as: "What is the threshold when it is economic to begin treatment?", "What is the appropriate timing in the season to begin treatment?", "What frequency of treatment is needed to break up the life cycle of the mite?". These are just a few of the complex set of new questions raised by this survey and they will not be easily answered without a much deeper understanding of the taxonomy, ecology and reproductive cycles of the various mite species exposed by this study.

There is much more basic work to be done. Even though there are two practical companion projects (TU10004 and TU10005) aimed at providing industry with better control measures, these trials on their own will not provide the necessary data to take us forward to where we need to be in terms of our understanding of the complex ecology partially exposed by our survey results. This survey, simple as it was yet important in terms of outcomes, is only the first step on what will be a long and complex voyage of discovery to investigate further what is a very real and important economic problem in the whole turf industry.

TECHNOLOGY TRANSFER

Two presentations on the preliminary findings in this survey have been made, the first by Dr Loch at the annual Asian Turfgrass Seminar in Pattaya, Thailand (16 March 2011) which was repeated by Mr McMaugh at Turf Alive in Castle Hill, NSW (17 May 2011). A PDF copy of this PowerPoint presentation is attached as Appendix 3.

The first popular article to disseminate the results of our survey was published in the July-August 2011 issue of *TurfCraft International* (Appendix 4). On-going discussions with the editor of *Australian Turfgrass Management* should also see at least one further popular article on the outcomes of our survey published in that magazine in the near future. Consideration will also be given to the publication of scientific papers based on our survey results and on the review of literature included in this final report.

Training modules and seminars need to be further developed to disseminate the results of this survey throughout the turf industry. As part of this process, the identification of an affordable digital microscope (Appendix 1) which can be used with a laptop computer will help develop the skill base needed to deliver the findings of our survey to turf producers and facility managers, who deal with mite infestations at the 'grassroots' level.

RECOMMENDATIONS

We make the following recommendations, both to continue building the knowledge base initiated through our survey and also to build on that knowledge base in terms of industry outcomes.

1. Training seminars should be developed and provided to turf industry development officers as part of their role to provide a link between researchers and growers, and to other key turf producer personnel. At the same time, attendance at such training sessions should also be offered at their cost to facility managers (particularly in local councils) and to commercial product suppliers to improve the accuracy of technical 'information' being supplied to all sections of the turf industry.
2. As part of the training and information dissemination to industry, saleable materials such as CD-ROMs should be developed. Such materials would help disseminate information more widely, including to TAFE students who represent the next generation of turfgrass managers.
3. A follow-up project should be developed with the Department of Industry and Investment NSW to fund the final identification of the specimens saved from our survey down to species level (including the description of any new taxa) by Ms Knihinicki.
4. Consideration should be given to funding a post-graduate PhD study to document the life cycle and ecology (including predators) of *Dolichotetranychus* species in particular to provide better guidance for control 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.
5. An alternative would be to apply for an ARC (Australian Research Council) grant for a wider study on grass mites, and incorporating recommendation 4. An ARC Discovery grant does not require industry funding, but this category is very competitive and would probably have to highlight and build on the findings for the two *Sporobolus virginicus* samples which yielded four different species and two genera previously unrecorded from Australia (D.K. Knihinicki, unpublished observation 2011). ARC Linkage grants have a higher success rate, but do require roughly one-third of the funds to be contributed by industry partners.
6. 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. The two companion projects TU10004 and TU10005 will help to develop more effective miticide-based strategies. However, it is not possible to determine the effects on predators of miticides or insecticides used in turf until the identity of those predators has been determined (recommendation 4).

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APPENDIX 1 – Low-Cost Portable Microscopy

The recent development of portable USB-powered microscopes (also variously called USB microscopes, computer microscopes, or computer-connected microscopes) provides an inexpensive option for field monitoring and for those at the grassroots of the turf industry seeking to monitor their own situation regarding mites, small insects and disease lesions. Because it plugs into the computer via a USB port, a microscope of this kind has been described as being like a webcam with a macro lens. Instead of viewing through the eyepiece(s) on a conventional microscope, the specimen then is examined via the monitor on the attached laptop computer.

The quality and complexity of USB microscopes varies, but even the best of these should cost no more than about $200. Some of the cheaper models rely on ambient lighting and may have limited focusing capacity, while the better ones come with their own built-in illumination via 4 or 8 LED lights and so look rather like a torch but with a CMOS camera and focusing lens built in. The necessary operating software is supplied with the unit and is simply installed on the attached computer. Typically, however, the documentation on how to operate a USB microscope is rudimentary at best.

We are trialling the Taiwanese-made M503 model (available through Scientific Instruments & Optical Sales, QLD - http://www.sios.net.au/microscope-camera-systems/m503-usb-2mp-microscope). It has a quoted resolution of 2Mp for digital photographs. The M503 comes with an adjustable 8-LED light source, and is supplied with either a metal stand (the more stable and slightly more expensive option) or a tripod (Plate 18). Depending on which of the 3 clear eyepieces is attached, the quoted magnification range covers 10x-230x. The zoom focusing system is operated using the attached slide control, and gives two focal points at low and high magnification depending on the distance between the microscope lens and the specimen. The operating software is compatible with Windows XP, Vista, and Win 7. Digital images can be saved either in .JPG (still) or in .AVI (video) format.

For observations of mites, the greatest limitation of a USB microscope is the very restricted working space below the objective because the suspect plant material must first be broken up by dissection so that the areas beneath the leaf sheaths where the mites live can be viewed. For this purpose, a basic dissection kit should also be purchased together with the microscope. At high magnification, focussing is also more difficult because of the very narrow depth of field, particularly if there is any movement of the specimen or by the microscope.

Plate 18. M503 USB-powered microscope with stand (*left*) or tripod (*right*). *(Photographs: Scientific Instruments & Optical Sales).*

APPENDIX 2 – Predatory Mite - Gleneagle (QLD)

Two turf farms near Gleneagle (QLD) became concerned after observing large numbers of an unidentified big brown mite active in their production fields. These were mainly associated with buffalo grass affected by grey leaf spot disease, but also in green couch showing scattered yellowish growths (possibly affected by latent couch smut) and were found as well on bare ground. The mites were very active under good weather conditions, but hid and stayed still when they sensed the presence of an observer; after a short period during which the observer remained motionless, the mites would re-emerge once more. They were less active under windy conditions and on cold mornings.

Specimens trapped on sticky tape by turf growers were photographed (Plate 19), preserved in 70% ethanol and forwarded to Orange (NSW). These were identified as belonging to the family Parasitidae (D.K. Knihinicki, unpublished observation 2011), which includes about 29 genera and around 400 species grouped into two subfamilies (O'Connor and Klimov 2004). The parasitids are medium to large predatory mites, often yellowish to dark brown in colour, and feed on other micro-arthropods (including their eggs) and on nematodes (Zhang 2003; O'Connor and Klimov 2004). They live in a variety of habitats, including soil ecosystems, grassland, moss, forest litter, humus, dung, and decaying organic matter. Parasitid mites disperse during the deutonymph stage, usually phoretic on insects from the orders Coleoptera (beetles) and Hymenoptera (bees, wasps, ants and sawflies).

Plate 19. Dorsal *(left)* and ventral *(right)* views of predatory mite from turf farms near Gleneagle.

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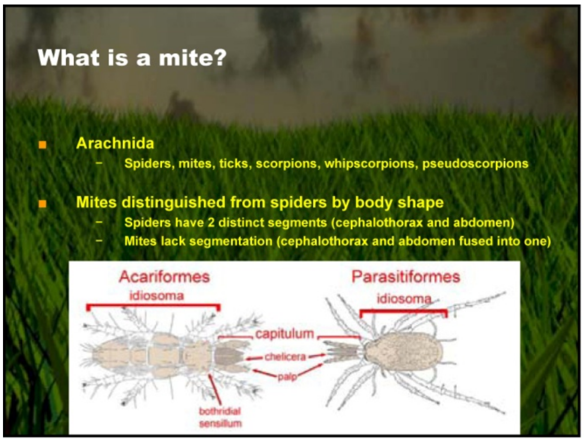
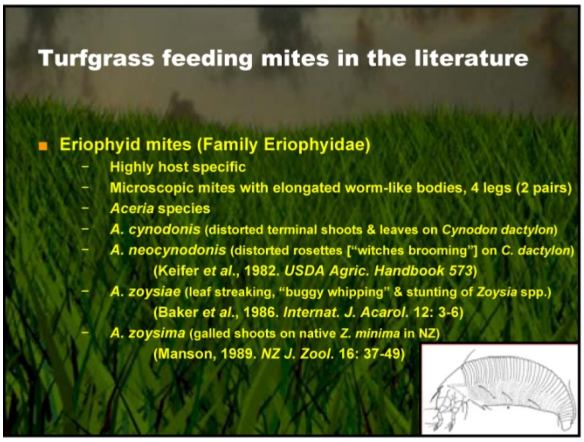
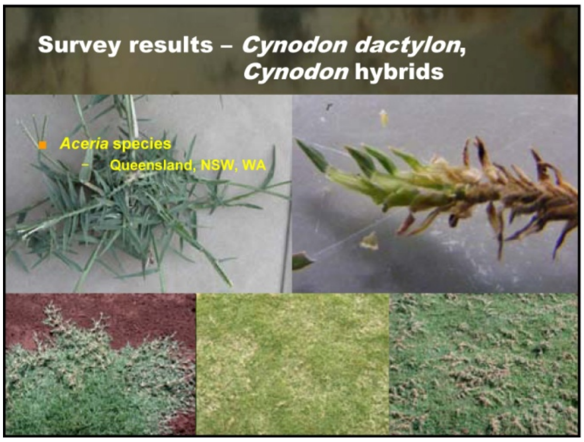
APPENDIX 3 – PowerPoint Presentation

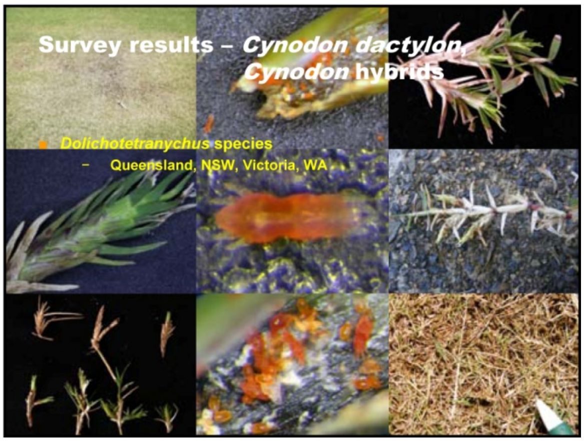

What is a mite?
Arachnida
Spiders, mites, ticks, scorpions, whipscorpions, pseudoscorpions
Mites distinguished from spiders by body shape
Spiders have 2 distinct segments (cephalothorax and abdomen)
Mites lack segmentation (cephalothorax and abdomen fused into one)
Acariformes
idiosoma
Parasitiformes
idiosoma
capitulum
chelicera
palp
bothridial sensillum

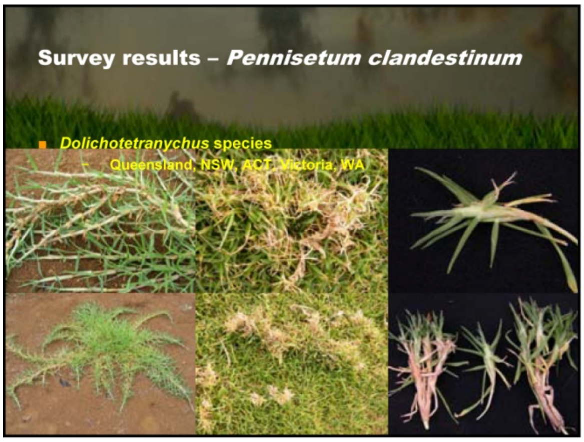

Turfgrass feeding mites in the literature
Grass-webbing mites (Family Tetranychidae)
Oligonychus araneum, O. digitatus
(Davis, 1968. J. Aust. Ent. Soc. 7: 123-126)
Not host specific
Occasionally affect turf & pasture grasses during hot dry weather

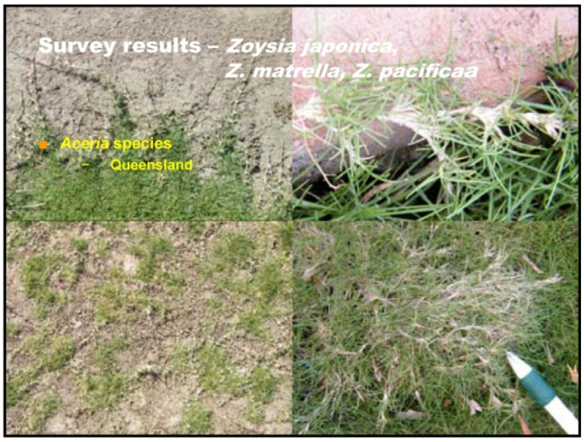

Turfgrass feeding mites in the literature
Eriophyid mites (Family Eriophyidae)
Highly host specific
Microscopic mites with elongated worm-like bodies, 4 legs (2 pairs)
Aceria species
A. cynodonis (distorted terminal shoots & leaves on Cynodon dactylon)
A. neocynodonis (distorted rosettes ["witches brooming"] on C. dactylon)
(Keifer et al., 1982. USDA Agric. Handbook 573)
A. zoysiae (leaf streaking, "buggy whipping" & stunting of Zoysia spp.)
(Baker et al., 1986. Internat. J. Acarol. 12: 3-6)
A. zoysima (galled shoots on native Z. minima in NZ)
(Manson, 1989. NZ J. Zool. 16: 37-49)


Turfgrass feeding mites in the literature
False spider mites (Family Tenuipalpidae)
Not as host-specific as the Eriophyidae
Dolichotetranychus species
11 species recorded on turf & other grasses
(Mesa et al., 2009. Zootaxa 2098)
D. australianus, D. summersi (on Cynodon dactylon – Australia & USA)
D. zoysiae (on Zoysia pacifica & Z. matrella – Japan)
D. carnea (on Sporobolus sp. – USA)
D. cracens (on Sporobolus cryptandrus – USA)
D. salinas (on Distichlis spicata – USA)
D. micidus, D. muhlenbergia (on Muhlenbergia spp. – USA)
D. macer (on Aristida namaquensis – South Africa)
D. repenae (on Panicum repens – India)
D. tenellae (on Eragrostis tenella – India)


Survey results – Cynodon dactylon, Cynodon hybrids
Aceria species
Queensland, NSW, WA


Survey results – Cynodon dactylon, Cynodon hybrids
Dolichotetranychus species
Queensland, NSW, Victoria, WA


Survey results – Pennisetum clandestinum
Dolichotetranychus species
– Queensland, NSW, ACT, Victoria, WA


Survey results – Zoysia japonica, Z. matrella, Z. pacificaa
Aceria species
– Queensland


Survey results – Zoysia japonica, Z. matrella, Z. pacifica
Aceria zoysiae
– Probably not present
– "Buggy-whip" symptoms (US publications) not seen in Australia
Photos: Dr Aaron Patton


Survey results – Zoysia matrella, Z. pacifica
Dolichotetranychus species
– Queensland


Survey results – Digitaria didactyla
Dolichotetranychus species
– WA
– Symptoms less obvious (poor root development, poor growth)


Where to from here?
The way forward
Detailed studies of life cycles & ecology
– Post-graduate student research
Possible relationship to secondary disease organisms
– e.g. summer decline in Cynodon greens
Alternate hosts
– Other introduced and native grasses (e.g. Sporobolus virginicus?)


Where to from here?
The way forward
Detailed studies of life cycles & ecology (including predators)
– Post-graduate student research
Possible relationship to secondary disease organisms
– e.g. summer decline in Cynodon greens
Alternate hosts
– Other introduced and native grasses
Effective control measures
– Partially mask effects of mites with water and N
– Repeat sprays with adulticide+ovicide to break life cycle
– New chemistry?
Increase industry awareness of problems & management
– Sod producers, facility managers, etc


The fairies at the bottom of the garden…
Turfgrass feeding mites
– Imaginary or real?

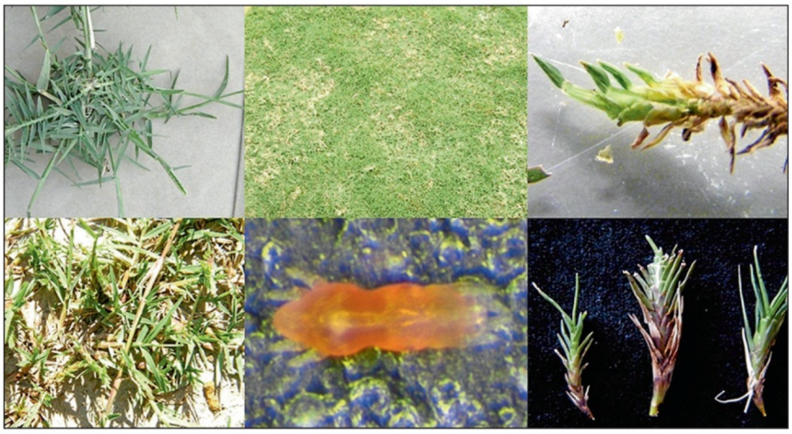

The fairies at the bottom of the garden…
Turfgrass feeding mites
– Imaginary or real?
Real!!!
– 3 different groups found on 8 different turfgrass taxa
Cause a lot of unsuspected damage
– Harvest-ready sod takes longer to grow in
– Greater losses during sod harvest (breakages)
– Slower-growing, less wear & drought tolerant for turf managers
Adds to costs of sod production & turf management
– Slower turn around for sod producers
– Higher water & N use for turf managers
– Inclusion of expensive unnecessary "water-saving" products

APPENDIX 4 –*TurfCraft International* Article (July-August 2011)

McMaugh P (2011) Project targets mite problem. *TurfCraft International* **139**, 57-58.

Project targets mite problem

By PETER McMAUGH



Mite damage on green couch: eriophyid mite symptoms (top), false spider mite symptoms (bottom) with female false spider mite (bottom centre).

MITES have been a well identified problem in warm-season turf grasses for more than 70 years. The only mites discussed in turf literature in Australia or taught in educational courses at TAFE and other institutions have been 'couch' mite.

When this mite has been discussed, in what little literature that has been available, it has almost universally been assumed that the mite in question has been *Aceria cynodoniensis* (also referred to in some early literature as *Aceria neocynodonis*), which is the mite to which the damage in *Cynodon* species (couch grasses) has been attributed in the United States.

The most common form of damage has been described as 'witches broom' and is the result of distorted growth forming rosettes on the terminal shoots of couch grasses, caused by mites living in the leaf sheaths of the affected grass.

The distortion is produced by internode shortening and shortening of the leaves. The exact mechanism by which this distortion is controlled is not known.

While working at the Australian Turfgrass Research Institute in the 1960s, the author of this report often observed eriophyid mites in couch grass samples which had been stained with lactophenol cotton blue dye for general pathological examination.

Because eriophyid mites are extremely small and are colourless, they are very difficult to see during dissection of plant material. I generally assumed these mites were *Aceria* species but because of the lack of resources was unable to take identification any further.

In 1986, Judy McMaugh published with Lansdowne Press the book *What GARDEN PEST or DISEASE Is That?* Under the entry for 'Couchgrass mite', the pest is identified as *Dolichotetranychus australianus*. This attribution obviously came from a reference to a paper by Womersley, a South Australian acarologist working at the South Australian Museum in the 1940s who identified this mite in a couch sample sent from south-east Queensland.

This very limited knowledge base, coupled with my experience of more than 30 years as a turf producer and 45 years as a consultant, convinced me that 'mites' where a hugely limiting constraint on efficient economic turf production as well as the recovery of turf after wear in public recreation areas and domestic lawns.

The generic description of mite damage as witches broom also clearly did not fit every case of growth distortion that we were seeing in the field.

During a visit to Chile in 2009 to attend the International Turfgrass Society Research conference on a HAL- ▶

Know-how for Horticulture™

INSIDE TURF GROWER

Broken rolls on a commercial turf farm showing high percentage loss resulting from mite damage that has led to many small clumped plants with poor lateral runner extension and a subsequent lack of turf strength.

funded study tour (TU08044), our group observed extreme growth distortion in kikuyu which had all the symptoms of mite damage but was much worse than anything seen in Australia.

Some of the symptoms of mite damage seen in commercial row plantings of both green couch and kikuyu include looping of runners into aerial positions without attachment to the soil. This is also a feature of some buffalo grasses which occurs in mature swards and is generally described as 'porpoising'.

Distorted terminal growth, particularly in turf regrowth after harvest, leads to many small clumped plants with poor lateral runner extension and a subsequent lack of turf strength. At harvest time, this results in rolls breaking up or tearing on the harvest conveyer and loss of product which can be as high as 30%.

While these consequences of mite infestation are well known, it was evident that we still did not know what mites we were dealing with.

Without knowing which mites were attacking which grasses, we have no idea of what to do about effective control.

That was the motivation for applying for industry funding through HAL to take this first step on the road to hopefully unravelling this complex area in turf. Subsequent to HAL approval, Project TU10002 began.

> "This project has enabled us for the first time to understand which types of mites are present in which grasses."

Project survey

The survey was conducted across the whole of Australia. However, the number of grass species surveyed varied from State to State depending on the range of grasses grown, and instead of four warm-season grasses being included, six grass species were in fact surveyed.

The sampling was done across a wide cross-section of sites and, in all, almost 120 samples were taken.

For the survey results to be valid, a specialist acarologist, Danuta Knihinicki of I & I NSW at Orange, NSW, was included in the team and it was she who confirmed the mite types found.

What we have found as a result of the survey is that where we were expecting to find mostly eriophyid mites (mites with two pairs of legs – which we did find in couch), we found a predominance of false spider mites (tenuipalpids, with three pairs of legs) on both couch and, especially, kikuyu.

We also found some predatory mites (mostly tetranychids with four pairs of legs) and true spider mites.

What we have also noted is that the eriophyids appear to disappear at low temperatures while the *Dolichotetranychus* we found in kikuyu seem to remain active at low temperatures. We have also seen quite different symptoms exhibited in couch under attack by these two different groups of mites.

This project has enabled us for the first time to understand which types of mites are present in which grasses. The results have changed the previously assumed situation with mite species and have added at least two new mites that were previously unknown to our information bank.

The scope of the project has not enabled us to take every mite down to species identification level.

However, it sets the scene for improved lifecycle studies in the future and for chemical treatments which are the subject of two further HAL projects to be completed.

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