Rathayibacter toxicus, select agent

Melodie L. Putnam, Oregon State University Plant Clinic, Corvallis Oregon

INTRODUCTION

Rathayibacter toxicus is a nematode-vectored toxigenic bacterium (order Actinomycetales) that causes disease in livestock that eat infected host plants. This poster summarizes the facts relevant to the disease to promote awareness of this select agent.

Why is *R. toxicus* considered a high risk pathogen?

• *R. toxicus* produces corynetoxins, which are among the most lethal naturally produced poisons. The toxins have caused death of tens of thousands of sheep and thousands of cattle in Australia in a single year.

• The effect is cumulative.

• The toxins are heat stable.

• *R. toxicus* is seed-borne.

• Animal disease due to *R. toxicus* could present a threat to the livestock industry in the US, valued in 2008 at over $95 billion for cattle, and $836 million for sheep.

• There is a possibility of human poisoning from eating contaminated cereals or animals with sub-clinical disease.

Figure 1. Sheep dead from eating infected annual ryegrass (*Lolium rigidum*) in South Australia. Sandy soil has been excavated by padding convulsions. Photo: J.W. Finnie, Inst. of Medical and Veterinary Science (IMVS), South Australia

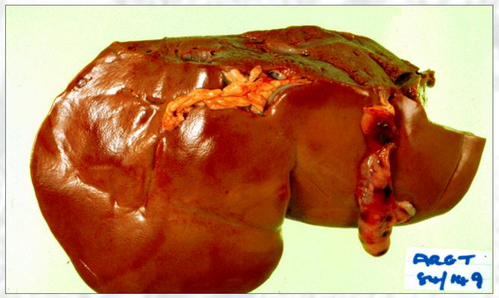

Figure 2. Liver with gallbladder haemorrhage from sheep that has died from *Rathayibacter toxicus* poisoning. Photo: J.W. Finnie, IMVS

THE BACTERIUM

Rathayibacter toxicus is a Gram positive pleomorphic bacterium. It requires a nematode vector to initiate disease in plants, where it causes gumming disease, named for the bacterial exudates sometimes present on infected grasses. In Australia, the principal and natural vector is *Anguina funesta*.

The bacterium produces a number of toxins which cause frequently lethal neurological and liver damage to animals that ingest contaminated fodder (Figures 1 and 2). Toxin production may be associated with a bacteriophage that is absent in non-toxin-producing bacterial isolates.

Disease in animals, when fed on infected *Lolium rigidum*, is known as annual ryegrass toxicity (ARGT). When animals eat infected *Agrostis avenacea* or *Polypogon monspeliensis*, the malady is called flood plain staggers. Animals fed nematode galls that are not colonized by bacteria do not become ill.

DISTRIBUTION

R. toxicus occurs in Australia and South Africa. There is a suspicion that it was present in Oregon from about 1940 to the mid-1960's, but this was never confirmed.

DISEASE CYCLE

In Australia, nematode and bacteria-infested seed galls oversummer in the ground. The nematodes survive the high temperatures of late summer as stage 2 juveniles (J2s) in a state of anhydrobiosis in the galls.

When fall rains moisten the galls, the J2s emerge and migrate through the soil to germinating seeds, carrying the bacteria adhered to their cuticles. The nematodes find their way to the grass meristem, and remain there until the inflorescence forms, which they then infect. The presence of the nematode stimulates gall formation, replacing the intact seed with a nematode-infested gall. The J2s undergo three molts, become adults, and lay eggs in the galls. The stage 2 juveniles form within the eggs.

If environmental conditions are favorable, the bacteria also proliferate and can outgrow the nematodes, killing them and forming a bacterial gall. Bacterial slime is produced and may be visible as a sign of disease. Bacterial- and nematode-galls drop to the soil, completing the disease cycle.

SYMPTOMS

Nematode galls in *Lolium rigidum* are more easily observed after removal of the palea and lemma (Figures 3 and 4), which obscure the galls in the field. *R. toxicus* may remain within the nematode gall, or may grow outside of it to encompass other parts of the head, in which case yellow bacterial slime (Figure 5) may be evident, along with occasional distortion of the seed head The bacterial slime turns orange as it dries. In some grass hosts, *Anguina* galls are larger than normal seeds and are readily detected.

Figure 3. Healthy *Lolium rigidum* seed (left), *Anguina funesta* gall (center), and *Rathayibacter toxicus* colonized nematode gall (right). Photo: Ian Riley, South Australian Research and Development Institute (SARDI).

Figure 4. *L. rigidum* seed with associated tissues: healthy (left), nematode gall (center), and bacterial gall (right). Photo: J. Allen, Department of Agriculture and Food, Western Australia.

GRASS HOSTS

Naturally infected plants	Plants infected under artificial conditions
Lolium rigidum L. (annual ryegrass)	*Austrodanthonia caespitosa* (Gaudich.) H. P. Linder (white top or ringed wallaby grass)
Agrostis avenacea J. F. Gmel (common blown grass)	*Ehrharta longiflora* Schrad (annual veldtgrass)
Lolium multiflorum L. (Italian ryegrass) [2]	*Triticum aestivum* L. (wheat) [3]
Polypogon monspeliensis (L.) Desf. (annual beard grass)	
Infrequently infected	
Vulpia myuros (L.) C. C. Gmel. (rat-tail fescue) [1]	*P. paradoxa* L. (paradoxa grass) [1]
Phalaris minor Retz. (lesser canary grass) [1]	*Avena fatua* L. (wild oat) [1]

[1] found only in mixed stands with heavily infested *L. rigidum*
[2] Dominie Wright, Department of Agriculture and Food, Western Australia (personal communication)
[3] naturally infected wheat has never been found in Australia (I. Riley, personal communication)

NEMATODE VECTORS

The principal vector, *Anguina funesta* Price, Fisher & Kerr, (= *A. lolii*), is known only from Australia.

A. funesta has incorrectly been considered a synonym of the more cosmopolitan *A. agrostis.* Based on allozyme and sequence analyses of ribosomal ITS regions, *A. funesta* is considered a separate species. Morphology alone is not sufficient to distinguish between these two nematodes.

However, other nematodes of the same genus can also vector the bacterium under experimental conditions, including *Anguina agrostis*, *A. tritici*, *A. australis*, and an *Anguina* sp. from *Holcus lanatus*.

Figure 5. Gumming disease of *Lolium* due to *Rathayibacter toxicus*. Photo: J. Allen, Department of Agriculture and Food, Western Australia

Figure 6. Bacterial head blight of orchardgrass (*Dactylis glomerata* L. due to *Rathayibacter rathayi*. Photo: M. L. Putnam

SIMILAR DISEASES

Rathayibacter rathayi, a non-toxigenic species, causes bacterial head blight or Rathay's disease in orchardgrass (*Dactylus glomerata* L.) in the US. Symptoms look superficially similar (Figures 5 and 6) to infection by *R. toxicus* and molecular or serological confirmation of the causal agent is required to differentiate the two bacterial species.

R. tritici causes spike blight or gumming disease in wheat, but is not known to be present in the US. *R. iranicus* also causes a gumming disease of wheat, and has been documented only from Iran and Turkey.

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Background image of *Anguina funesta* in modified ovary gall courtesy of J. Collier, Department of Agriculture and Food, Western Australia.