Asexual Epichloë Fungi—Obligate Mutualists

Subjects: Mycology

Contributor: Caradus John , Stuart Card , Katrin Hewitt , David Hume , Linda Johnson

Asexual *Epichloë* are obligate fungal mutualists that form symbiosis with many temperate grass species, providing several advantages to the host. These advantages include protection against vertebrate and invertebrate herbivores (i.e., grazing livestock and invertebrate pests, respectively), improved resistance to phytopathogens, increased adaptation to drought stress, nutrient deficiency, and heavy metal-containing soils. Selected *Epichloë* strains are utilised in agriculture mainly for their pest resistance traits, which are moderated via the production of *Epichloë*-derived secondary metabolites. For pastoral agriculture, the use of these endophyte infected grasses requires the balancing of protection against insect pests with reduced impacts on animal health and welfare.

alkaloids animal toxicosis biocontrol endophyte fescue ryegrass

Microbial endophytes, primarily comprising archaea, bacteria, fungi, or viruses, are associated with most plant species [1][2]. The term ‘endophyte’ was derived from the Greek words ‘*endon*’ (within) and ‘*phyton*’ (plant) [3], and initially included both pathogenic and beneficial microorganisms [4]. However, the term endophyte has now become synonymous with mutualism in reference to microbes that spend all or part of their life cycle within the plant host while causing no apparent disease symptoms [5][6], and provides a net benefit outcome to both itself and the host plant [7].

Asexual *Epichloë* endophytes (previously belonging to the taxonomic genus *Neotyphodium* [8]) were identified in the 1980/90s as the cause of two economically important diseases that affected livestock that grazed fescue in the USA and perennial ryegrass in New Zealand, namely fescue toxicosis [9] and ryegrass staggers [10], respectively (**Figure 1**). These obligate symbionts are mutualistic, relying on the host plant for their growth, survival, and transmission through hyphal colonisation of the host’s seed [11]. These endophytes exhibit a degree of host-specificity within the cool-season grasses of the Pooideae, whereby *Epichloë* species are naturally restricted to a host grass genus or closely related genera within a grass tribe [12][13][14]. Asexual *Epichloë* spend their entire life cycle within the plant host growing systemically within shoot tissues between plant cells [15][16][17] (**Figure 2**). However, their bioactivity towards certain pests in the rhizosphere [18] can be attributed to the mobility of fungal secondary metabolites in the roots, produced during the symbiosis, within the plant vascular system [15][16].

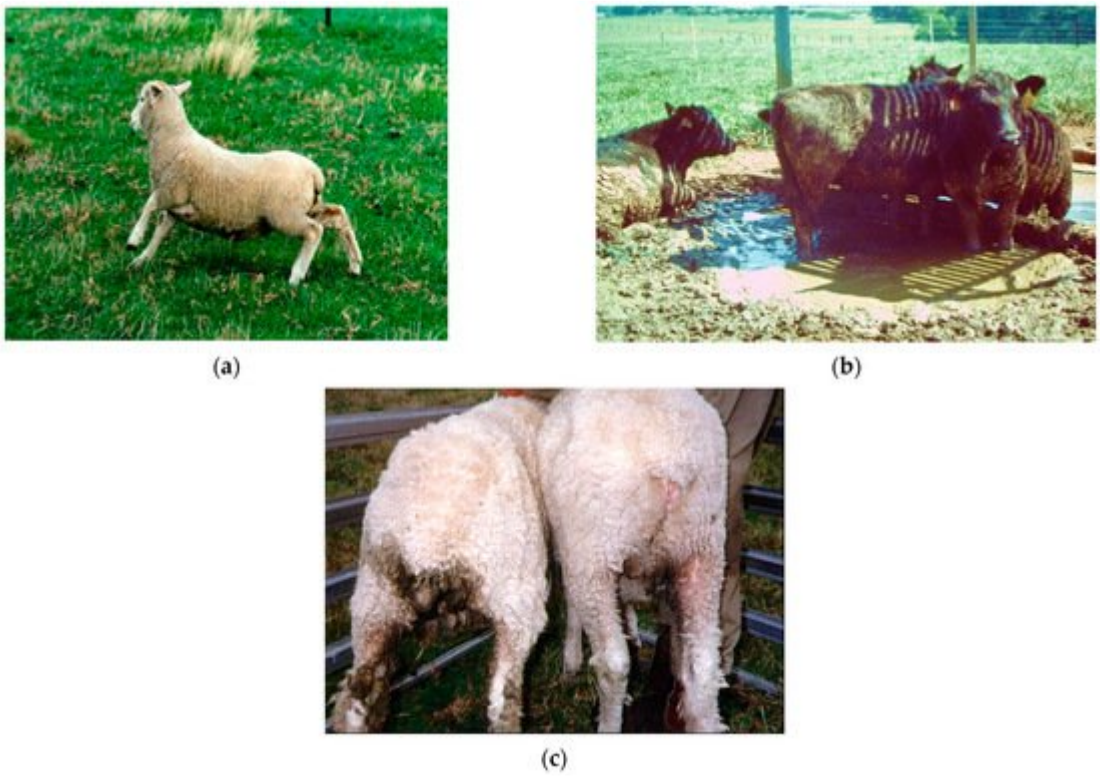

Figure 1. Animal ailments caused by some *Epichloë* secondary metabolites: (**a**) ryegrass staggers caused by lolitrem B, and (**b**) fescue toxicosis caused by ergovaline; (**c**) fecal soiling in the breech area ('dags') of sheep exacerbated, on left, by a combination of secondary metabolites. (Images (**a**) and (**c**) courtesy of L. Fletcher; image (**b**) courtesy of J. Bouton).

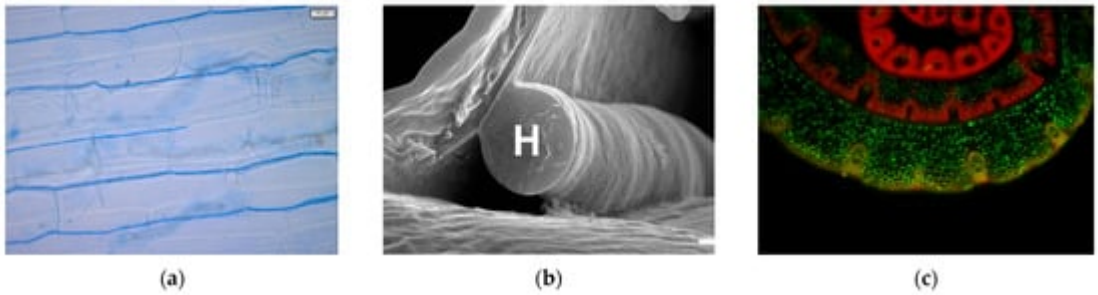

Figure 2. *Epichloë* hyphae, (**a**) stained with aniline blue (bar top right is 20µm) (image courtesy of W. Zhang), and (**b**) shown in a transmission electron micrograph growing between leaf cells with the hyphae labelled H (image courtesy of W. Zhang); and (**c**) a cross section of a grass tiller showing hyphae of a strain modified to express green fluorescent protein (image courtesy of M. Christensen).

Epichloë-derived secondary metabolites protect the host plant from herbivores—both vertebrates and invertebrates. However, the effect on ruminants and several non-ruminants including horses, camels, white rhinoceros, and alpacas [19] can be detrimental and, when first discovered, removal of these endophytes from grasses was considered the best solution. However, in many temperate regions of the world, such as New Zealand, these *Epichloë* endophytes are essential for pasture persistence. Novel endophyte strains have now been identified and commercialised that provide the host grass with tolerance/resistance to pests, diseases, and some

abiotic stresses while reducing or eliminating the debilitating animal health and welfare issues [20]. These endophytes can be transferred between plants through artificial infection [21].

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