Available online at www.sciencedirect.com
ScienceDirect
Veterinary Parasitology 144 (2007) 293–298
veterinary parasitology
www.elsevier.com/locate/vetpar

The ecology of nematode-trapping hyphomycetes in cattle dung from three plateau pastures

Hongyan Su [a,b], Yu'e Hao [c], Minghe Mo [a], Keqin Zhang [a,*]

[a] *Laboratory for Conservation and Utilization of Bio-resources, Yunnan University, Kunming Yunnan 650091, PR China*
[b] *Department of Biology and Chemistry, Dali College, Dali, Yunnan 67000, PR China*
[c] *Department of Public Health, Nanhua University, Hengyang, Hunan 421001, PR China*

Received 2 June 2006; received in revised form 13 October 2006; accepted 17 October 2006

Abstract

This paper investigated the influence of season and altitude on the occurrence of nematode-trapping fungi in cattle faeces. Six hundred and sixty samples of cattle faeces deposited on three plateau pastures with different altitudes in the west of Yunnan Province, China, were examined in 2004. A total of 17 species of nematode-trapping hyphomycetes were isolated from these samples. The predominant species from all three plateau pastures were *Arthrobotrys oligospora*, *A. musiformis*, *Monacrosporium ellipsosporum*, and *M. thaumasium*. Species with adhesive networks were the most frequently isolated. Overall, species diversity index was negatively correlated with altitude and was different among seasons within the same site. Levels of diversity were highest in the summer, followed by autumn, spring, and winter. The conidia of the hyphomycetes isolated here germinated normally on medium containing cattle faeces, with species developing adhesive networks having the highest rate of germination. However, the rate of conidial trap (CT) formation was lower in species with adhesive networks than those in other species.

Keywords: Cattle faeces; Fungal diversity; Plateau pasture; Predacious fungi

1. Introduction

Parasitic gastro-intestinal nematodes can significantly limit livestock productivity. For years, chemical control with anthelmintics has been a cost-effective method in limiting livestock losses caused by parasitic nematodes (Waghorn et al., 2002). However, the use of chemicals has its problems. For example, the incidence of resistance to anthelmintics is increasing and without the development of novel anthelmintic compounds, the long-term viability of chemical control will face serious challenges. In addition, there is an increasing public pressure to reduce the amount of chemical residues in both animal tissues and on pastures (Waller, 1997; Jackson and Coop, 2000; Waghorn et al., 2002).

In an attempt to solve some of these problems, a number of alternatives to the chemical control of gastro-intestinal nematodes of livestock have been developed. Biological control has received increasing attention lately, particularly in response to the demand for ‘‘natural’’ and ‘‘organic’’ livestock products.

Biological control can effectively decrease larva population of gastro-intestinal nematodes on the pastures (Larsen, 1999). At present, biocontrol of the gastro-intestinal nematodes is based on the use of nematophagous fungi against the pre-parasitic (larval) forms of trichostrongyloids (Larsen, 1999). Nematophagous fungi predate the infective larvae of nematodes

* Corresponding author.
E-mail address: kqzhang111@yahoo.com.cn (K. Zhang).

0304-4017/$ – see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.vetpar.2006.10.012

and can survive gut passage in ruminants. It has been shown that they can effectively control helminthosis (Waller and Faedo, 1996; Hay et al., 1997; Manueli et al., 1999). As a result, the application of nematophagous fungi onto pastures has increased rapidly in recent years (Faedo and Krecek, 2002; Chartier and Pors, 2003; Dimander et al., 2003).

Nematophagous fungi are classified into four major classes: trapping, endoparasitic, opportunistic and toxic fungi. Nematode-trapping fungi are common in animal faeces and soil (Duddington, 1951, 1955; Juniper, 1953, 1954, 1957; Larsen et al., 1994; Mahoney and Strongman, 1994; Hay et al., 1997). Many of these nematode-trapping fungi are active against the free-living stages of gastro-intestinal nematodes (Waller and Faedo, 1993). Among these, *Arthrobotrys flagrans* (Dudd.) Sidorova, Gorlenko & Nalepina (= *Duddingtonia flagrans* (Dudd.) R.C. Cooke) (Cooke, 1969) has been selected for commercial development, mainly because this fungus can produce a large number of chlamydospores from laboratory cultures. These spores are capable of surviving passage through the gastro-intestinal tract. Trials with *A. flagrans* have been successful in New Zealand (Waghorn et al., 2003), Sweden (Dimander et al., 2003), and the United States (Terrill et al., 2004).

The study of dung and its ecology as a source of nematode-trapping fungi for use in the biocontrol of helminthes is thus a potentially valuable approach. Nematode-trapping fungi have been investigated on a worldwide basis and the distributions of the fungi in soils, aquatic environments, and animal dung has been studied (Juniper, 1953, 1954, 1957; Fowler, 1970; Gray, 1987; Persmark et al., 1996; Persmark and Jansson, 1997; Hay et al., 1997, 1998; Manueli et al., 1999; Saumell and Padilha, 2000; Ghahfarokhi et al., 2004; Hao et al., 2005). However, little attention has been given to this group of fungi in cattle faeces from plateau pastures.

In this study, three genera (*Arthrobotrys* Corda, *Monacrosporium* Oudem, and *Dactylella* Grove) were studied in cattle faeces deposited on three plateau pastures with different altitudes over four seasons. The conidial germination of nematode-trapping hyphomycetes and their CT formation in cattle faeces were investigated along with the potential inhibitory effects of the faeces on the development of these fungi.

2. Materials and methods

2.1. Area description

Three plateau pastures were selected. The first is the Huadian pasture (25°53′N, 100°00′E, altitude 2940 m), located in Dali County, in western Yunnan Province, China. The average annual temperature in this area is 8.2 °C, with a high of 13.7 °C and a low of 2.2 °C. Average annual rainfall is about 1846.4 mm. This pasture faces the north and is surrounded by mountains and covered with bush and tall trees. The second is the Dariba pasture (26°51′–28°52′N, 99°20′–100°19′E, altitude 3240 m), located in Xianggelila County in northwestern Yunnan Province. It has an average annual temperature of 5.4 °C, with a high of 10 °C and a low of 0 °C. It has an average annual rainfall of 700 mm. The third is the Baima pasture (27°33′–29°15′N, 98°36′–99°33′E, altitude 3900 m), located in Deqin County, in western Yunnan Province. The average annual temperature is 4.7 °C with a high of 8 °C and a low of −1 °C. The average annual rainfall in the Baima pasture is approximately 661.3 mm.

2.2. Sampling

Samples of decayed cattle faeces from the three natural pastures were collected in 2004. From each pasture, 60 samples, each of 50–100 g, were collected in March, June, September and December, respectively, and randomly. In December no sample was collected from the Baima pasture as it was covered in snow. In total, 660 samples were collected. Prior to each collection, the dung surface was removed so that the collection of dried-out dung was avoided. All the samples were put into sterile plastic bags and stored in a refrigerator at a temperature of 4 °C before being processed.

2.3. Isolation and identification of nematode-trapping fungi

To isolate nematode-trapping fungi (NTF), about 2–3 g dung of each sample was spread onto a Corn Meal Agar plate (20 g cornmeal, 18 g agar, 1000 ml of water, CMA). Approximately 200 nematodes (*Panagrellus redivivus*) suspended in 0.1 ml distilled water were added as bait for the NTF on each plate.

Each sample was plated on three different petri dishes, resulting in a total of 180 plates for the 60 samples from each site at each season. The samples were stored at room temperature (about 20–28 °C) for 20 days after which the entire surface of the petri dish was observed under a dissecting microscope for the presence of NTF. The fungi were identified and recorded according to the taxonomic keys provided by Li et al. (2000).

2.4. Data analysis

Species diversity of NTF was measured using the Shannon–Weaver index H':

$$H' = -\sum_{i=1}^{s} P_i \log_e P_i$$

(Shannon and Weaver, 1963) where P_i is the proportion of the ith species and S the number of species at the site.

2.5. The inhibitory effect of cattle faeces on isolated nematode-trapping hyphomycetes

The materials and methods for this section can be referred to the paper by Persmark and Nordbring-Hertz (1997). Ten species (Table 3) isolated here were used for this investigation.

3. Results

3.1. Nematode-trapping hyphomycetes

Our results showed that nematode-trapping hyphomycetes were present in the cattle faeces from all three pastures throughout the year. Seventeen nematode-trapping species of fungi were isolated from the samples: eight belonged to the genus *Monacrosporium*, six belonged to *Arthrobotrys*, and three belonged to *Dactylella*. Of the 17 species, *Arthrobotrys oligospora*, *A. musiformis*, *Monacrosporium ellipsosporum*, and *M. thaumasium* were the most common in the three pastures. Other isolated species were present in the dung at very low frequencies (Table 1).

Of the recorded species, eight (47%) produced adhesive networks, three (17.6%) produced adhesive knobs, two (11.8%) produced adhesive knobs and non-constricting rings, and one (5.9%) produced both constricting rings and adhesive branches. More information with regard to the type of traps recorded for each species is shown in Table 2.

3.2. Differences in nematode-trapping hyphomycetes in pastures at different altitudes

Our analysis suggested that the species richness of the NTF decreased with increasing altitude. Of the three pastures, the Huadian pasture at the lowest altitude had the highest number of species (15) of NTF whilst the Dariba pasture at the highest altitude had the lowest number of species (7) (Fig. 1). Similarly, the Shannon–Wiener indices showed that the Huadian pasture had the highest year-round species diversity; followed by the Dariba pasture and the Baima pasture (Fig. 2). These results suggested a negative correlation between species diversity and altitude.

Table 1
Checklist of predacious fungi in three pastures (OF = occurrence frequency = the number of samples in which a certain species was isolated/total number of samples × 100%)

Species	Huadian OF	Dariba OF	Baima OF
Arthrobotrys cladodes	2.50		
Arthrobotrys conoides	1.50	3.36	2.27
Arthrobotrys musiformis	15.22	6.73	8.33
Arthrobotrys oligospora	17.25	12.98	11.36
Arthrobotrys superba	3.04	2.40	2.03
Arthrobotrys vermicola	2.03	0.48	
Dactylella clavata	1.52		
Dactylella leptospora	1.01		
Dactylella sp.	0.50		
Monacrosporium candidum	3.05		1.51
Monacrosporium cionopagum	3.15	1.50	
Monacrosporium doedycoides	1.52		
Monacrosporium drechsleri	2.05	1.92	
Monacrosporium ellipsosporum	19.29	16.35	12.12
Monacrosporium longiphorum	2.03	0.96	1.51
Monacrosporium parvicolle	0.76	0.48	
Monacrosporium thaumasium	3.15	3.37	
Species richness	15	10	7

3.3. Seasonal changes of nematode-trapping hyphomycetes in the pastures

Our results indicated seasonal differences of NTF in all three pastures (Fig. 1). Both species richness and species diversity were highest in the summer, followed by autumn, spring and winter (Fig. 2).

3.4. The inhibitory effect of cattle faeces on 10 species of the isolated nematode-trapping hyphomycetes

Table 3 showed that most of the conidia in cattle faeces germinated normally and some CT were formed. The conidial germination rate was the highest for species producing adhesive networks [between 90.2% (*M. thaumasium*) and 95.5% (*A. oligospora*)], whilst their CT formation rate was the lowest [between 0 (*M. thaumasium*) and 6.2% (*A. conoides*)]. The conidial germination rate for species producing knobs or stick branches was lower [between 23.3% (*D. leptospora*) and 40.6% (*M. cionopagum*)] than that for adhesive networks, whilst their CT formation rate was higher,

Table 2
Type of traps produced by isolated species

Type of traps	Species isolated	Species number	Percentage
Adhesive nets	*Arthrobotrys conoides*, *Arthrobotrys musiformis*, *Arthrobotrys oligospora*, *Arthrobotrys superba*, *Arthrobotrys vermicola*, *Arthrobotrys cladodes*, *Monacrosporium longiphorum*, *Monacrosporium thaumasium*	8	47
Constricting rings	*Monacrosporium doedycoides*	1	5.9
Adhesive knobs	*Monacrosporium drechsleri*, *Monacrosporium ellipsosporum*, *Monacrosporium parvicolle*	3	17.6
Adhesive knobs and non-constricting rings	*Dactylella leptospora*, *Monacrosporium candidum*	2	11.8
Adhesive branches	*Monacrosporium cionopagum*	1	5.9
No traps	*Dactylella clavata*, *Dactylella* sp.	2	11.8

ranging from 50.2% (*M. cionopagum*) to 89.3% (*D. leptospora*). Species producing rings were greatly inhibited in their conidial germination by cattle faeces. The normal germination rate for *M. doedycoides* in this experiment was only 20.2%. However, its CT formation rate was very high (92.2%).

4. Discussion

In our study, 17 species of NTF were isolated from cattle faeces deposited on three plateau pastures. In an analysis of sheep dung, it was reported that 83 and 58% of sheep faecal samples contained nematophagous fungi 3 days after deposition in February and April, respectively (Hay et al., 1997).

At present, there are several hypotheses for the entry of nematode-trapping fungi into animal dung. One is the splash dispersal of conidia from the air or soil. Another is anthophilous dispersal by soil invertebrates, such as mites (Hay et al., 1997). It is also possible that nematode-trapping fungi appearing in the upper layers of soil and foliage are also able to grow into the dung (Hay and Regnault, 1995; Persmark et al., 1996) and that the fungal traps could also be carried into the dung by soil infected by nematodes (Nansen et al., 1988).

The ideal temperature for the growth of nematode-trapping fungi is between 15 and 30 °C, consistent with our observed spatial and temporal patterns of species diversity among nematode-trapping fungi (Cooke, 1963; Pandey, 1973). In this study, all the sampling sites were in plateau pastures with low temperatures (1–18 °C) and the isolation of 17 species of nematode-trapping fungi proved that plenty of nematode-trapping fungi could survive at low temperatures (1–18 °C). Of the 17 species of NTF isolated in this study, the predominant species were *A. oligospora*, *A. musiformis*, *M. ellipsosporum*, and *M. thaumasium*, different from the dominant ones (*A. oligospora* and *M. eudermatum*) found in sheep dung (Saumell and Padilha, 2000). The predominant species isolated from these wild animals also differed from those isolated from domestic animals, possibly due to the different ecological conditions within these animals and their faeces. It is interesting to note that three of the four major species isolated here (75%) produced adhesive networks. This is in agreement with the observation by Saumell and

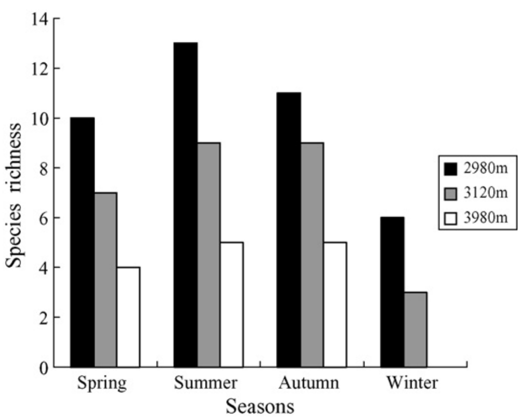

Fig. 1. Species richness of nematode-trapping fungi from the three plateau pastures in 2004.

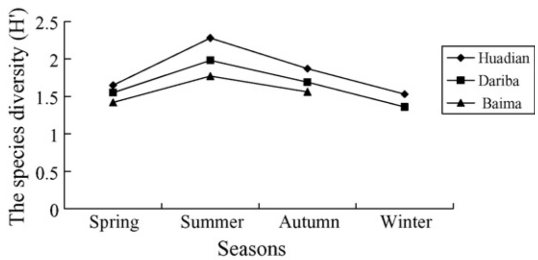

Fig. 2. The species diversity for three pastures in 2004.

Table 3
The inhibition effects of cattle faeces on 10 species of nematode-trapping fungi

Species	Regular germination rate of spore (%)	CT %	Traps
Arthrobotrys conoides	94.1	6.2	Adhesive networks
Arthrobotrys musiformis	93.6	0	Adhesive networks
Arthrobotrys oligospora	95.5	3.8	Adhesive networks
Arthrobotrys superba	93.2	0	Adhesive networks
Monacrosporium thaumasium	90.2	0	Adhesive networks
Monacrosporium drechsleri	37.3	52.7	Adhesive knobs
Monacrosporium ellipsosporum	39.2	66.6	Adhesive knobs
Monacrosporium cionopagum	40.6	50.2	Adhesive branches
Monacrosporium doedycoides	20.2	92.2	Constricting rings
Dactylella leptospora	23.3	89.3	Adhesive knobs and non-constricting rings

Padilha (2000). It appears that fungi are able to colonize faeces, develop in different seasons and in pastures at different altitudes.

Our study showed that species with adhesive networks were the most frequently isolated. A similar result was reported by Gray (1987), Persmark and Jansson (1997) and Hao et al. (2005). They speculated that the species producing adhesive networks grew faster, required fewer nutrients, and had greater saprotrophic abilities. Our study also showed that nematode-trapping hyphomycetes with different traps were not necessarily inhibited by cattle faeces. Conidia of nematode-trapping hyphomycetes can germinate and form CT in cattle faeces. The high germination rate of conidia from species producing adhesive networks could have contributed to the high frequency of isolation of this group of NTF from cattle dung.

In contrast, the conidial germination rate of species with other traps was lower and their CT formation rate was higher. This suggests that the saprophytic ability of these species might be weaker and they mainly depended on their traps to obtain nutrition. As a result, their frequency is low in the dung when isolated through single conidium.

Similar to the results from our study, the frequency of nematophagous fungi in sheep faeces appears to be also influenced by the season (Fowler, 1970; Persmark et al., 1996; Saumell and Padilha, 2000). Together, these studies identified that the highest numbers of nematode-trapping fungi were recorded in late summer and autumn. It is likely that high humidity, high temperature and increased precipitation in the summer months encourage the growth of nematode-trapping fungi. During the raining season from June to September in Yunnan, faecal samples could maintain sufficient moisture thus facilitating the colonization of the faeces by the nematode-trapping fungi. In the dry and cold months of March and December, the number of nematode-trapping fungal species is the lowest because dry and cold conditions do not support fungal growth and colonization.

The Shannon–Wiener indices indicated that the species diversity was negatively correlated with the altitude of the study sites. Studies of sheep dung have also shown a similar pattern (Fowler, 1970; Saumell and Padilha, 2000). Despite 17 species of NTF being isolated from the three plateau pastures in this survey, only those which are capable of surviving the harsh gut passage in ruminants can be considered as potential biocontrol agents worthy of further investigation. Whether the fungi isolated here can survive the gut environment needs to be further studied.

Acknowledgements

We thank Dr. J.S. Deng for her guidance for fungal identification in this study. We thank Dr. D.W. Hu and Dr. T. Li for their advice and enthusiastic help with polishing this manuscript. The suggestions and comments from the anonymous reviewers are greatly appreciated. Finally we thank our Canadian friend Mrs. Teri Woods and our Australian friend Mr. Iain Davey helping us revising and polishing this manuscript. This work was sponsored by projects from Major State Basic Research Development Program (approved No.2003CB415102), the Department of Science and Technology of Yunan Province (2005NG05) and the Department of Science and Technology of Yunan Province (2005C0076M).

References

Chartier, C., Pors, I., 2003. Effect of the nematophagous fungus, *Duddingtonia flagrans*, on the larval development of goat parasitic nematodes: a plot study. Vet. Parasitol. 34, 221–230.

Cooke, R.C., 1963. Ecological characteristics of nematode-trapping hyphomycetes. I. Ann. Appl. Biol. 52, 431–437.

Cooke, R.C., 1969. Two nematode-trapping hyphomycetes, *Duddinggonia flagrans* gen. et comb. nov. and *Monacrosporium mutabilis* sp. nov. Trans. Br. Microsc. Soc. 53, 315–318.

Dimander, S.O., Hogland, J., Uggla, A., Sporndly, E., Waller, P.J., 2003. Evaluation of gastro-intestinal nematode parasite control strategies for first-season grazing cattle in Sweden. Vet. Parasitol. 111, 193–209.

Duddington, C.L., 1951. The ecology of predacious fungi. I. Preliminary survey. Trans. Br. Microsc. Soc. 34, 322–331.

Duddington, C.L., 1955. Fungi that attack microscopic animals. Bot. Rev. 21, 377–479.

Faedo, M., Krecek, R.C., 2002. Possible application of a nematophagous fungus as a biological control agent of parasitic nematodes on commercial sheep farms in South Africa. J. S. Afr. Vet. Assoc. 73, 31–35.

Fowler, M., 1970. New Zealand predacious fungi. N. Z. J. Bot. 8, 203–302.

Ghahfarokhi, M.S., Abyaneh, M.R., Bahadori, S.R., Eslami, A., Zare, R., Ebrahimi, M., 2004. Screening of soil and sheep faecal samples for predacious fungi: isolation and characterization of the nematode-trapping fungus *Arthrobotrys oligospora*. Ir. Biomed. J. 8, 135–142.

Gray, N.F., 1987. Nematophagous fungi with particular reference to their ecology. Bio. Rev. 62, 254–304.

Hao, Y.E., Mo, M.H., Su, H.Y., Zhang, K.Q., 2005. Ecology of aquatic nemaode-trapping hyphomycetes in southwestern China. Aquat. Microb. Ecol. 40, 183–189.

Hay, F.S., Niezen, J.H., Bateson, L., Wilson, S., 1998. Invasion of sheep dung by nematophagous fungi and soil nematodes on a hill country pasture in New Zealand. Soil Biol. Biochem. 30, 1815–1819.

Hay, F.S., Niezen, J.H., Miller, C., Bateson, L., Robertson, H., 1997. Infestation of sheep dung by nematophagous fungi and implications for the control of free-living stages of gastro-intestinal nematodes. Vet. Parasitol. 70, 247–254.

Hay, F.S., Regnault, L., 1995. Introduction of the endoparasitic nematophagous fungus *Verticillium balanoides* into white clover (*Trifolium repens*) by its host, stem nematode (*Ditylenchus dipsaci*). Aust. Plant Pathol. 24, 249–251.

Jackson, F., Coop, R.L., 2000. The development of anthelmintic anti-inhibition in sheep nematodes. Parasitology 120, S95–S107.

Juniper, A.J., 1953. Some predacious fungi occurring in dung. I. Trans. Br. Microsc. Soc. 36, 356–361.

Juniper, A.J., 1954. Some predacious fungi occurring in dung. II. Trans. Br. Microsc. Soc. 36, 356–361.

Juniper, A.J., 1957. Dung as a source of predacious fungi. Trans. Br. Microsc. Soc. 40, 346–348.

Larsen, M., 1999. Biological control of helminths. Int. J. Parasitol. 29, 139–146.

Larsen, M., Faedo, M., Waller, P., 1994. The potential of nematophagous fungi to control the free-living stages of nematode parasites of sheep: survey for the presence of fungi in fresh faeces of grazing livestock in Australia. Vet. Parasitol. 53, 275–281.

Li, T.F., Zhang, K.Q., Liu, X.Z., 2000. Taxonomy of Nematophagous Fungi. Chinese scientific & technological Publication, Beijing.

Manueli, P.R., Waller, P.J., Faedo, M., Mahommed, F., 1999. Biological control of nematode parasites of livestock in Fiji: screening of fresh dung of small ruminants for the presence of nematophagous fungi. Vet. Parasitol. 81, 39–45.

Mahoney, C.J., Strongman, D.B., 1994. Nematophagous fungi from cattle manure in four state of decomposition at three sites in Nova Scotia. Can. Mycologia 86, 371–375.

Nansen, P., Grønvold, J., Henriksen, S.A., Wolstrup, J., 1988. Interactions between the predacious fungus *Atherobotrys oligospora* and third-strage larvae of a series of a series of animal-parasitic nematodes. Vet. Parasitol. 26, 329–337.

Pandey, V.S., 1973. Predatory activity of nematode-trapping fungi against the larvae of Trichostrongylus axei and Ostertagia ostertagi: a possible method of biological control. J. Helminthol. 48, 35–48.

Persmark, L., Banck, A., Jansson, H.B., 1996. Population dynamics of nematophagous fungi and nematodes in an arable soil: vertical and seasonal fluctuations. Soil Biol. Biochem. 28, 1005–1014.

Persmark, L., Jansson, H.B., 1997. Nematophagous fungi in the rhizospere of agricultural crops. FEMS Microbiol. Ecol. 22, 303–312.

Persmark, L., Nordbring-Hertz, B., 1997. Conidial trap formation of nematode-trapping fungi in soil and soil extracts. FEMS Microbiol. Ecol. 22, 313–323.

Shannon, C.E., Weaver, W., 1963. The Mathematical Theory of Communications. University of Illinois Press, Urbana, 367 pp.

Saumell, C.A., Padilha, T., 2000. Influence of weather and time of deposition on sheep faeces colonization by nematophgous fungi in the Minas Gerais State, Brazil. Appl. Soil. Ecol. 14, 63–70.

Terrill, T.H., Larsen, M., Samples, O., Husted, S., Miller, J.E., Kaplan, R.M., Gelaye, S., 2004. Capability of the nematode-trapping fungus *Duddingtonia flagrans* to reduce infective larvae of gastro-intestinal nematodes in goat faeces in the southeastern United States: dose titration and dose titration and dose time interval studies. Vet. Parasitol. 120, 285–296.

Waghorn, T.S., Leathwick, D.M., Chen, L.Y., Gray, R.A.J., Skipp, R.A., 2002. Influence of nematophagous fungi, earthworms and dung burial on development of the free-living stages of Ostertagia (Tekadirsagua) circumcincta in New Zealand. Vet. parasitol. 104, 119–129.

Waghorn, T.S., Leathwick, D.M., Chen, L.Y., Skipp, R.A., 2003. Efficacy of the nematode-trapping fungus *Duddingtonia flagrans* against three species of gastro-intestinal nematodes in laboratory faecal cultures from sheep and goats. Vet. parasitol. 118, 227–234.

Waller, P.J., Faedo, M., 1993. The potential of nematophagous fungi to control the free-living stages of nematode parasites of sheep. Screening Studies 49, 285–297.

Waller, P.J., Faedo, M., 1996. The prospects for biocontrol of the free-living stages of nematode parasites of livestock. Int. J. Parasitol. 26, 915–925.

Waller, P.J., 1997. Anthelmintic anti-inhibition. In: Barrell, G.K. (Ed.), Animals Industries Workshop. Lincoln University, Canterbury, New Zealand, pp. 129–140.