FUNGI FORAGERS

No. 10, August 2018

OUR PURPOSE: TO RAISE AWARENESS AND INTEREST IN FUNGI OF THE CAIRNS REGION

This newsletter is not formally published and is not associated with any club or organisation, but is emailed free of charge to anyone who may be interested. Anyone who wishes to contribute to the newsletter with observations, anecdotes, corrections, comments or photographs is welcome to do so. Although this "newsletter" is science-based we try not to make it too "scientific". We recognise that there are school children, bush-walkers and others just interested in fungi, and we hope this leaflet will become a medium for furthering that interest. The emphasis is on fungal biology rather than identification.

Barry Muir, Editor Jenn Muir

CORRECTIONS

In Cairns Fungi Foragers (CFF) number 9, the Slime Mould Special, I stated in paragraph 2: "Then the cell enlarges and grows and adds more nuclei: effectively becoming a giant multicellular amoeba that crawls around feeding on decaying material, bacteria and other fungi as it goes". I should have said "multinucleate" rather than multicellular. A multicellular organism is made up of many cells, each with its own nucleus (the thing inside the cell that contains its DNA). A multinucleate organism is one that has only one cell but many nuclei. There is also some debate about whether slimeys should be in their own Kingdom or not, but we'll leave that up to the experts to debate.

These inaccuracies were picked up by Sarah Lloyd, an expert on slime-moulds from northern Tasmania who read the article in CFF No. 9. Sarah has a website that is devoted to slimeys and well worth a look. She has also published a book on slimeys and details are available on her website;
https://sarahlloydmyxos.wordpress.com/

CARNIVOROUS FUNGI

Last issue we discussed slime-moulds – shape-shifting blobbys that will never (we hope) take over the world. In this issue we take the matter further to discuss fungi that munch animals, so be careful in the garden if you happen to be a nematode worm. If you do happen to be a nematode with a computer to read this message, then you are probably smart enough to stay out of the way of these fungi.

Nematodes are very tiny worms that live in the upper part of the soil, in pastures (especially in animal dung), decaying leaf litter, mangroves, and in shallow ponds and swamps. There are gazillions of nematodes in rainforest litter and soils. Nematodes are the most readily available prey for hungry fungi in poor soils where the fungi have trouble getting nutrients any other way. The habit of feeding on nematodes has evolved many times among fungi, as is shown by nematode-predator fungi being found in all major fungal groups. There are at least 160 known species of fungi that have taken up eating nematodes.

Nematode munching fungi have been found throughout the world in a wide range of habitats and climates. For example, one species, *Arthrobotrys oligospora* (it has no common name) has been found in Europe, Asia, India, Africa, North and South America, Australia and New Zealand but appears to prefer the warmer climates. Most of the nematode-attacking fungi that have been studied are those that attack nematode pests of interest to farmers, gardeners and foresters. The global cost of plant-parasitic nematodes is approximately $100 billion (US) per year, so control of these pests using fungi to do the job is worth studying.

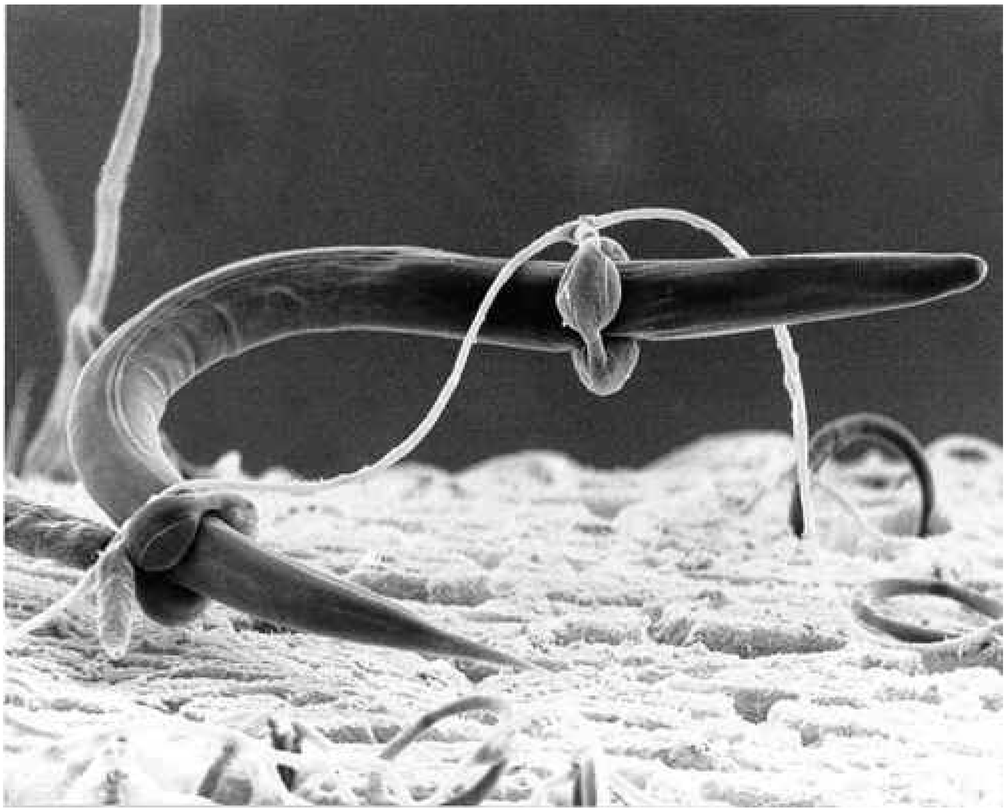
As well as in grassland, shrubland, plantations, sheep and cattle yards, domesticated and non-domesticated animal dung and gardens, the fungi have also been found in heavily polluted areas, mine-sites contaminated with heavy metals like lead and copper, soils chemically treated with fungicide (where it obviously didn't work!), decaying plant material, leaves, roots, moss, and near the roots of various bean plants, barley, and tomatoes.

The carnivorous fungi can be divided into four main groups according to the methods they use to catch their prey. Some use a lasso or net, some use an adhesive, and some produce a poison. Some use their spores to enter their prey or are egg parasites, inserting their hyphal tips into the eggs or cysts, or into female nematodes before the eggs are even deposited.

Adding green manure to soils has been found to increase nematode-trapping behaviours because it increases the number of nematodes. A chemical called "nemin" produced by nematodes has been found to stimulate trap formation in the fungi, so nematodes may actually stimulate the fungus to produce more traps to catch them in – they are their own worst enemy!

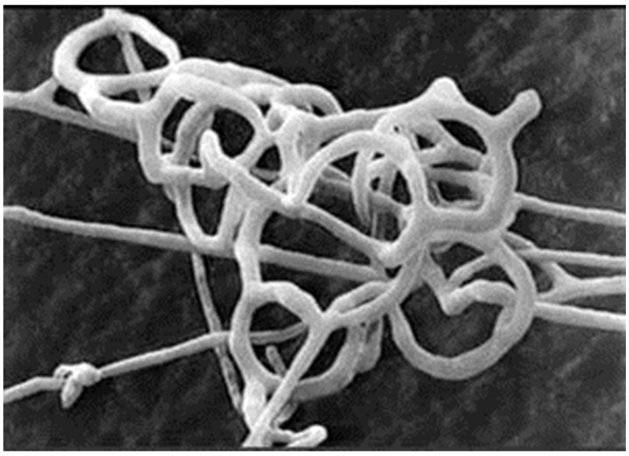
Lassos, Nets and Spiny Balls

To form a lasso, a normal hypha forms a branch which then curves back towards the original hypha to form a three-celled loop with a stalk and then the branch re-joins with the original hypha. This process may form just a single loop or may occur several times to form a net of complex multi-branched hyphae. The loops or net immediately become sticky. Some nematode crawls blindly through the soil and accidentally (or perhaps encouraged by chemical attractants) enters the ring. Because the nematode is thicker in the middle than at the ends it gets jammed in the ring. Generally, rings are almost impossible to dislodge because of a sticky coating, and during the struggle the ring may break from the weak point. The ring or net is flexible, which results in 'drag', tiring the nematode. The struggle further increases the number of places the nematode is stuck to the fungus. Multiple points of adhesion make the net capable of catching both large and small nematodes easily. Once trapped, if the nematode is jammed in the ring, it can move away, but eventually is killed by the fungus. This may be a mechanism which helps to distribute the fungus through the soil.



A nematode in deep trouble, caught up in two lassos. Picture Source: https://microbewiki.kenyon.edu/index.php/Nematode_trapping_fungi

Some fungi go a step further and produce constricting rings. Constricting rings are produced in the same way as non-constricting rings, but the supporting stalk is shorter and stouter. The nematode enters the ring, friction created by its body induces the ring to swell inwardly by pumping water into the cells. The inflated rings may be up to three times larger than the original size. This can occur in less than 1/10 of a second resulting in the body of the nematode being deeply constricted and trapped. Struggle between nematode and fungus goes on for a few minutes. Thereafter the nematode becomes still, probably killed by toxins rather than the constriction, and within the hour hyphae from the ring cell penetrate the body and consume it internally through long, unbranched absorptive hyphae that grow along the nematode body. The nutrients are then transported to the rest of the fungal body for use in growth and reproduction.



An example of a fugal net intended to catch nematodes. Picture Source: http://schaechter.asmblog.org/schaechter/2011/09/how-to-escape-a-deadly-embrace.html

Arthrobotrys oligospora, one of the net-building species of fungus, can detect the presence of nematodes nearby in the soil and only builds its snares when they are present. This is presumably because building the net is a highly energy-consuming process; the fungus is alerted to the presence of the nematode by detecting the pheromones (chemical "perfumes") which the worms use to communicate. The fungus takes active steps to attract its prey by producing pheromones that mimic those used by the nematode to find food and attract mates. It is interesting that not all nematodes are caught by the net as the nematode needs to be in contact with the net for a short time for adhesion to occur. Nematodes have been found to quickly move away from any net if there is only instantaneous contact. One or several very brief contacts are not enough for adhesion between the nematode and net to occur.

Not all the nematode predators use lassos or nets. At least one species of large fungus, the Shaggy Ink Cap, *Coprinus comatus,* attacks soil nematodes with a structure known as a spiny ball. This is used to damage the nematode surface to immobilise it, then the hyphae pierce the skin and digest the contents.

Sticky Stuff

As discussed, many of the lassoing and net-forming species of fungus employ glue to help trap their prey. Some others use sticky hyphal strands or adhesive knobs. Hyphae may produce adhesive at any point in response to nematode contact, or the hyphae are coated with adhesive along their entire surface. At the point of hyphae where contact is made for capture, a thick and yellowish chemical material is secreted by some fungi.

Some produce short, erect branches a few cells in height, on or below the substrate. A thin film of adhesive material is coated over the whole surface of the branch. In other species a distinct adhesive ball-shaped cell is produced at the tip of a slender non-adhesive stalk made up of one to three cells. A thin film of adhesive material is produced over the surface of the knob. If a nematode is caught by a knob, it is soon attacked by several knobs which grow toward it.

Poisons

A substance found in paralysed nematodes was found to be capable of paralysing healthy nematodes, and it was originally thought the toxin was made by the fungus. However, it was later found that toxic levels of a substance called linoleic acid was naturally present in the fungus and it was this that killed the nematodes. Linoleic acid, by the way, is quite common in nature and is also found in vegetable oils, nuts and seeds. However, some fungi, such as *Coprinus comatus* and the family Pleurotaceae, which includes *Pleurotus* and *Crepidotus*, are known to produce a whole range of specific toxic substances which immobilise nematodes.

Spores that are Eaten by the Worms

Most internally-parasitic fungi that attack nematodes have swimming spores or spore-like reproductive cells called conidia that are attracted to soil nematodes and tend to congregate around their mouths. Having penetrated the nematode either through the skin or inside the gut, the hyphae grow throughout the nematode, absorbing its tissues. Escape tubes emerge from these and grow through the skin. In due course, further mobile spores exit through these, ready to infect other nematodes. At least one species of fungus, called *Harposporium anguillulae*, produces dangerous-looking sickle-shaped conidia that are eaten by the nematode and lodge in its oesophagus (food pipe) or gut from where they invade the tissues. Nasty little suckers!

Egg Parasites

In egg-parasite species, when a fungal hypha encounters an egg, a swollen structure develops at the point of contact. Then a narrow infectious tube penetrates the shell of the egg. After penetration, the infectious hyphae swell up and form a post-penetration bulb. From this bulb there develops numerous irregularly branched absorption hyphae that consume egg nutrients and devour the developing juvenile nematode before growing on towards nearby eggs.

Internal Parasites

Unlike nematode-trapping fungi, the internally parasitic fungi do not produce extensive mycelia outside the nematode body. Instead, some produce special swimming conidia which track down nematodes by swarming, then form tough spore-like structures called cysts near a nematode's mouth or anus. The cysts produce a germ tube which penetrates the nematode through its body opening; by dissolving a hole through its skin; or by firing a hyphal "dart" into it under pressure. In other species the spores may be consumed by the nematode and lodge in the throat or gut. The infectious hyphae grow well inside the nematode body and digest the contents. During the initial phases of this process, the host remains alive, but as the fungus spreads from the gut to the surrounding tissues in the latter stages of infection, death of the host soon follows. Special spores are then produced, inside the body, and from which numerous spores with swimming tails are released and the cycle is repeated.

It is interesting to note that no competing fungi or bacteria have been found in nematodes which are being consumed by a fungus. This suggests that an antibiotic is released by the fungus inside the nematode, preventing other fungi and bacteria from competing with the parasite.

It is not our usual practice to publish "technical" papers in CFF but sometimes it is necessary to get them into the public arena, and certainly before the next wet season in the hope that more observations will be made regionally and tied to rainfall.

IMPACT OF ABOVE AVERAGE RAINFALL IN 2018

by Barry Muir & Raymond Palmer.

Most fungal observations depend on the fruiting of fungi after periods of rainfall. But can there be too much of a good thing? Observations in Tropical North Queensland (TNQ) suggest that under certain circumstances fruiting body production can slow or stop temporarily after excessive rainfalls. Ray Palmer has been collecting observations on fungal fruiting at Redlynch in the Cairns region since 1980. Observations suggest that, in most years, fungal fruiting follows roughly the same pattern: a bout of heavy rain quickly triggers many fruiting bodies and some perennial species are stimulated to reproduce again after a period of dormancy. In 2018, however, the wet season (primarily from January to March inclusive in Cairns) was more intense than it has been for several years in the region of TNQ between Cow Bay near Daintree in the north and Tully in the south, a distance of about 200 km (Figure 1).

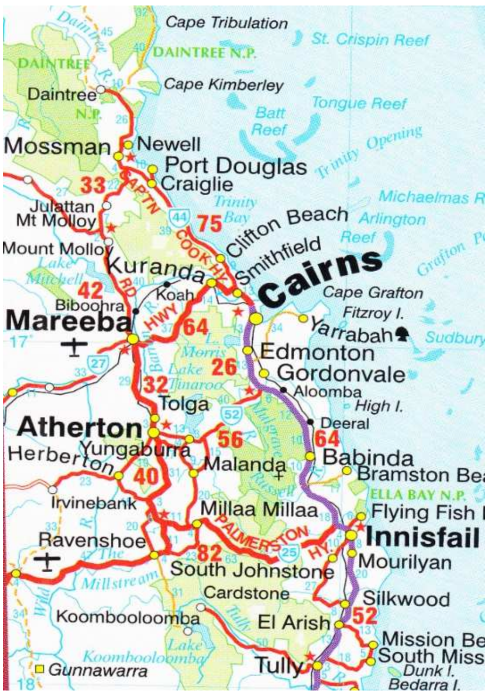


Figure 1. Area Under Discussion

Interestingly, Daintree near the north of the study area and Babinda at the south both received below average rainfalls. This resulted from monsoon troughs and low-pressure systems (see Cairns Fungi Foragers No. 3, 2017) which hovered over the study area for the whole three months of the 2018 wet season.

Rainfall data were collected from 16 locations, four being private rainfall records (Cow Bay near Daintree, Mossman (2), and the Cairns suburbs Whitfield and Redlynch), and the remainder from Bureau of Meteorology data. The long-term rainfall means are all from the nearest Bureau of Meteorology stations, with the exception of Redlynch where Ray Palmer has been collecting data since 1980. Results are presented in Figure 2.

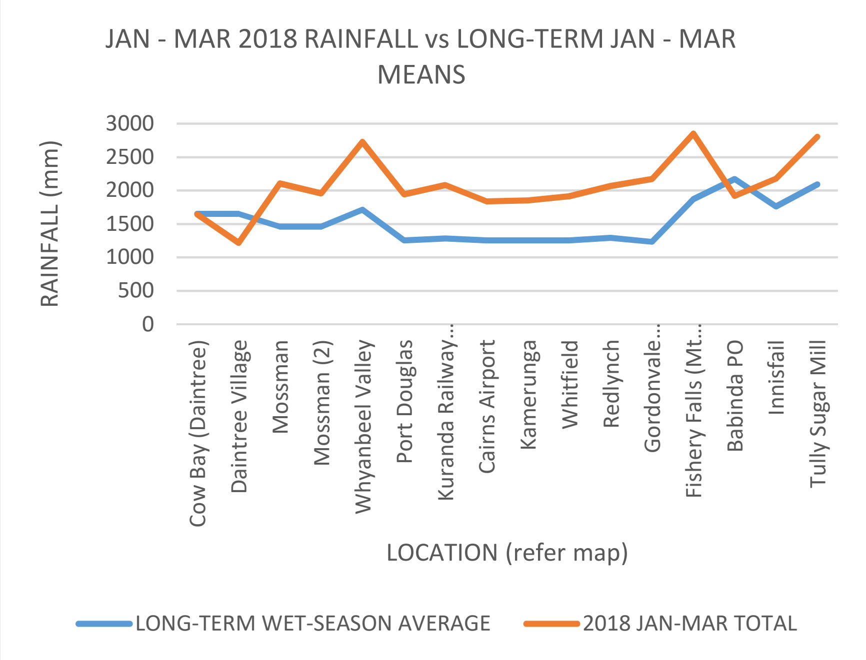


Figure 2: January to March total rainfall in 2018 compared with long-term mean rainfalls for the same period.

Observations at Mossman (2) (Fay Adams pers. comm.); Kuranda (Fay Adams pers. comm.); Kamerunga (a Cairns suburb, Peter Newling pers. comm.); Redlynch (a Cairns suburb, Ray Palmer pers. comm.); and Whitfield (Cairns suburb)/Goomboora Park (Barry Muir) all indicate that fungal fruit bodies of all types were scarce to almost absent following the period of extreme rainfall. The actual falls recorded in each month at the six sites of fungi observation are presented in Table 1.

LOCATION	JAN	FEB	MAR	2018 TOTAL	LONG-TERM MEANS*
Cow Bay	585	306	751	1642	1652
Mossman (2)	299	415	1242	1956	1461
Kuranda	515	350	1216	2081	1285
Kamerunga	567	340	945	1852	1261
Whitfield	593	330	991	1914	1261
Redlynch	544	453	1069	2066	1293

*Bureau of Meteorology data except for Redlynch

Table 1. Location, rainfall by month in 2018, total rainfall over the three-month period and long-term means

Cow Bay near Daintree had an average rainfall (five years of data) and produced the usual expected suite of species more or less in average abundance (Connie Kerr pers. comm.). There were several features which seemed to correspond with the lack of fruiting bodies in the areas with above-average rainfall.

Firstly, at the start of the extreme wet period, fruit body production appeared to be normal or close to normal in both abundance and species diversity. However, towards the end of the extreme wet period, not only were many fungi pulverised by the heavy rainfalls, many simply stopped fruiting. It is presumed that the species that normally grow on wood had simply used up the readily available resources because the moist growing period was simply too long, and breakdown of the cellulose in the wood and other food sources could not keep up.

Secondly, the fungi that grow on soil, apart from being pulverised or physically removed by water flow or soil erosion, may have been unable to cope with the waterlogged soil. After the extended rainfall a strong acid smell pervaded some areas of forest, and it is suspected that waterlogged soil had become sour and no longer suitable for the fungi to grow on. At Whitfield/Goomboora Park a sour smell dominated the soil when it was dug up and mean soil pH had dropped from about 6.5 to as low as pH 3.5 (strongly acid) in some locations. This odour persisted for about two weeks after the rains ceased, but gradually improved, although there were no new flushes of fungi. After 17 days without more than a few very light showers, there was another rainy period (31 mm over three days) and again the typical “first-flush” fungi such as *Psathyrella, Bolbitius, Phallus* and *Cyathus* appeared, but in small numbers. Soil pH had risen to about 6.0 (near-neutral) in the areas tested. This may indicate that the soils had experienced a period of re-oxygenation and perhaps bacterial and fungal breakdown in the soil, releasing nutrients which then allowed a new growth of fruiting bodies when rain again fell.

The third observation was that several species of fungi were recorded which had been scarce or absent (based on casual observation) in previous years. Some coral fungi appeared to be slightly more abundant than usual and *Cookeina sulcipes* and *C. tricholoma*, although common, seemed to be unusually common.

Acknowledgements and Sources

Thanks are extended to Fay Adams for rainfall data from Mossman (2) and observations at Kuranda; Connie Kerr for rainfall data from Cow Bay near Daintree; Barry Muir provided rainfall and observational data for Whitfield/Goomboora Park; Peter Newling for observations at Kamerunga; and Ray Palmer provided rainfall and observational data for Redlynch. Jennifer Muir edited the paper.

Reference

Muir, BG (2017). *Climate and Fungi near Cairns.* Cairns Fungi Foragers No. 3 (June 2017), pp1-2.

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