Mycological Research News[1]

This month *Mycological Research News* features recent work on the advance of the daisy rust *Puccinia distincta* in the UK, questions whether hyphae should be viewed as eusocial, draws attention to work showing that fertilization with AM-fungi may promote desirable grass species, and introduces a freely accessible index of 340 K names of fungi now available on-line. The untimely death of one of *Mycological Research*'s editors, David A. Wood, is also reported.

Amongst topics covered by the 16 research papers in this issue are PCR-based techniques for the detection of *Fusarium oxysporum* and *Gremmeniella abietina.. Tuber dryophilum* shares a specific protein with *T. borchii*. Toxic ephrapectins occur in *Tolypocladium* species; the extracellular enzymes of *Trichoderma* strains able to grow at 5 °C are examined; nutrients favouring oxalic acid production in *Aspergillus niger* have been studied; and the branching of *Neurospora crassa* hyphae is predictive on rapid falls in temperature. Elegant colour and ultrastructural studies on the extracellular matrix of *Bipolaris sorokiniana* are presented. In addition to documentation of the daisy rust spread, the life-history of *Chrysomyxa woroninii* is elucidated and the success of *Lophodermium pinastri* along an altitudinal gradient discussed.

The growth of fungal partners from different lichens is compared, and cell wall polysaccharides are shown to be of taxonomic value in *Fusarium* and *Gibberella*.

Systematic papers include ones on *Pyrenopezia betulicola*, and microfungi on *Proteaceae*. New scientific names introduced are: *Kabatiella proteae, Lembosia proteae, Mycosphaerella stromatosa, Perennipora najenshana, Phloeosporella protearum, Pseudocercospora stromatosa, Septoria grandicipis, Stilbospora proteae, Teratosphaeria microsporum, Trimmatostroma microsporum,* and *T. elginense* spp. nov.; and *Diplotomma rivasmartinezii* (syn. *Buellia rivasmartinezii*) comb. nov.

IN THIS ISSUE

This issue includes the results of molecular studies which have developed PCR techinques for the detection of two fungi: one for *Fusarium oxysporum* which was tested against 23 other species of the genus and eight other fungi (pp. 518–526); and one for *Gremmeniella abietina*, the cause of Scleroderris canker of pine, which was effective on needles not showing symptoms (pp. 527–532). *Tuber dryophilum* proves to have the same ascoma-specific protein found in *T. borchii* but this was not present in three other members of the genus tested (pp. 533–536).

Toxic efrapectins have been discovered in *Tolypocladium* species, but not in sufficient amounts to cause insect death on their own (pp. 537–544). Fourteen of 360 *Trichoderma* strains tested were able to grow at 5 °C, and their antagonism to two plant pathogens and production of extracellular chitinases and β-glucosidases assessed (pp. 545–549). Oxalic acid is instrumental in the breakdown of rock and soil minerals; *Aspergillus niger* solubilized gypsum most effectively when grown on increased amounts of glucose, nitrate and urea (pp. 550–556). The branching of hyphae in *Neurospora crassa* displayed a predictive response on rapid downward tem-

perature shifts which consisted of lag, starburst and recovery phases (pp. 557–563).

The extracellular matrix of *Bipolaris sorokiniana* has been visualised by a variety of conventional and electron microscopic methods, the results of some of which are presented in colour, and their nature and role investigated (pp. 564–575).

Three papers examine the behaviour of plant pathogens. A remarkable spread of the rust *Puccinia distincta* on daisies in the UK documented on pp. 576–580 is discussed separately below (p. 514). Life-history and inoculation studies have established that the rust *Chrysomyxa woroninii* forms aecia on spruce and teliospores on *Ledum* species (pp. 581–586). Studies on altitudinal transects demonstrate that the colonization and fruiting of *Lophodermium pinastri* on *Pinus sylvestris* increases with altitude (pp. 587–594).

The information on the growth of the fungal partners of lichens in pure culture is meagre; a comparative study of five species revealed differences in germination and development rates (pp. 595–602). Cell wall polysaccharides in *Fusarium* and *Gibberella* have been purified, their structures determined and differences found which appear to have considerable potential as taxonomic aids (pp. 603–610). Other systematic papers in this issue show that *Pyrenopeziza betulicola* has a *Cylindrosporium* anamorph (pp. 611–617), describe ten new fungi on *Proteaceae* and make anamorph-teleomorph connections on this host family for the first time (pp. 618–636), and describe one new fungus on *Daphniphyllum* from Taiwan (pp. 637–639).

THE ADVANCE OF THE DAISY RUST

Preece, Weber & Webster (2000) have carefully documented the spread of *Puccinia distincta* on wild and cultivated varieties of *Bellis perennis* in Britain. The incident has sobering implications for plant health import regulations in relation to conservation, indicating the potential spread of rusts from cultivated to native plants.

The rust appears to be of Australian origin and its first record in Britain was apparently from cultivated daisies in Bristol in 1972. The infected material may, however, have come from continental Europe; the species is particularly well-known in Germany. After sporadic occurrences in other parts of southern England on cultivated varieties, the species then spread northwards and first made the jump to native daisies at Headingly, near Leeds, in 1987. Then, suddenly in 1997 the species became established on native daisies in many parts of England and Wales.

Two other rusts have been reported on daisies, *P. lagenophorae* and *P. obscura*. The former is exceptionally common and systemic on groundsel (*Senecio vulgaris*) and is separable by its teliospores from *P. distincta*. The latter forms teliospores and urediniospores on rushes (*Luzula* spp.) and only aecia on daisies; *P. obscura* is not regarded as a serious pathogen. The symptoms of *P. distincta* are quite characteristic (Fig. 1) and the species is unlikely to be confused with *P. obscura*.

The extent to which this rust will continue to spread and adversely affect native daisy populations is unclear, but the incident has shown that native plants in Britain are at risk from fungal pathogens introduced with cultivated plants. Plant health regulations have traditionally focused on crops, and not taken into account potential risks to closely related or conspecific native plants. The issue is not considered in national and European quarantine regulations (Smith *et al.* 1992). Indeed, how to monitor the health of imported garden plants will not be an easy task, but is a matter that needs to be addressed as a part of conservation strategies to protect the nation's biodiversity. In the wake of the ravages of Dutch elm disease (*Ophiostoma novo-ulmi*) in the 1970s–1980s, the risks are very apparent. Further, the danger could increase as global warming enables a wider range of plants to be grown in gardens. The issue was sadly not tackled in the UK
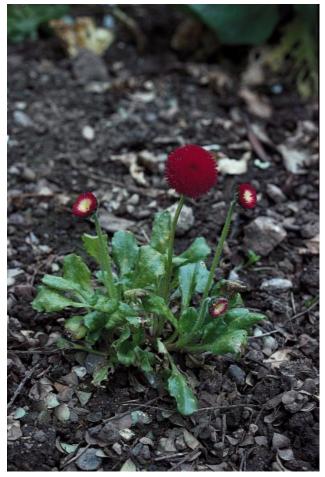

Fig. 1. *Puccinia distorta* with aecia on cultivated *Bellis perennis*. Photograph © J. Webster.

Biodiversity Action Plan (Department of the Environment 1994).

Department of the Environment (1994) *Biodiversity: the UK action plan*. Her Majesty's Startionery Office, London.

Preece, T. F., Weber, R. W. S. & Webster, J. (2000) Origin and spread of the daisy rust epidemic in Britain caused by *Puccinia distincta*. *Mycological Research* **104**: 576–580.

Smith, I. M., McNamara D. G., Scott, P. R. & Harris, K. M. (eds) (1992) *Quarantine Pests for Europe*. CAB International, Wallingford.

EUSOCIAL HYPHAE?

It is becoming increasingly evident that fungal growth is a much more complex process than just a turgid protoplasm pushing against a deformable cell wall. In this journal, Money (1999) touched on the possibility of two types of hyphal extension, invasive, and the other which he referred to as growth (which in this contribution I term non-invasive). I suggest that if we expand these ideas from a single hypha to a whole mycelium, then a number of important issues for discussion emerge.

Invasive hyphae generate internal hydrostatic pressures which enable them to penetrate or force their way through their substrata. The generation of these pressures requires a cell to be surrounded by a wall, and Money (1999) suggests that this may be the reason why hyphal walls originally evolved. That hyphae were required to be penetrative may also partly explain the characteristic hyphal shape. The tube with a dome is structurally very sound, but also bears a close resemblance to a drill bit. Non-invasive hyphae, in contrast,

extend despite little or no internal hydrostatic pressure, through the action or modulation of the cytoskeleton and/or cell wall (Money and Harold 1993, Kaminskyj and Heath 1996). Tip growth, with little or no turgor, has also been observed in some plant cells (Pickett-Heaps and Klein 1998).

A mycelium is a network of hyphae that, through the presence or absence of septa and septal pores, may or may not comprise a cytoplasmic continuum. For those that are cytoplasmically connected, all the hyphae will experience the same hydrostatic pressure, as it is not possible to have a pressure differential within a continuum. This rule will hold for coenocytic fungi and any septate fungus that has no plugged septa. Such mycelia will therefore, at any one time, be either invasive or non-invasive. One might expect that such a mycelium would be able to switch between growth types as necessitated by the environment. This would presumably require a 'regulatory centre' or some form of signalling mechanism between hyphae to allow a 'one change – all change' type of action.

The presence of complete or plugged septa, however, would enable some hyphae to generate higher internal pressures than others. This compartmentation raises the possibility of different modes of growth occurring concurrently in the same mycelium; different hyphae (or groups of hyphae) playing different physiological roles and, critically, displaying a mode of growth that reflects that role. These ideas are congruent with the suggestion of Rayner et al. (1995) that a mycelium is an 'intrinsically heterogeneous' system, which would indeed seem logical for a modular organism such as a fungus. It is interesting to note that most septate species studied to date are able to control their turgor, whereas coenocytic water moulds are not (Money 1994). While turgor control generally implies the maintenance of constant turgor over a wide range of external osmotic potentials, this ability is likely to involve processes such as the transport of solutes and/or synthesis of compatible solutes which would also facilitate the generation of high internal pressures (Clipson and Jennings 1992, Garrill 1995). Furthermore, in some compartments such as appressoria, turgor is thought to exceed 8 MPa (Howard et al. 1991)[2] which is approximately eight times what might normally be experienced by a hypha.

Perhaps, in thinking of a mycelium with different modes of growth occurring concurrently, the analogy of social behaviour among insects is apt. One of the traits by which we define eusociality in the Hymenoptera is a caste system, which enables a division of labour. Invasive hyphae may therefore perform an analogous task to worker insects foraging for food and new habitats, and supplying nutrients to other hyphae that are primarily concerned with reproduction or defence. Similar analogies have been used by Gould (1995) who, in attempting to define what constitutes an individual fungus, compared the mushrooms of an Armillaria mat to certain aphid castes.

It should be remembered that regardless of the magnitude of the pressure, the key to extension is having a tip that will yield to the pressure (or pushing force of an advancing amoeboid protoplasm), and at the same time provide sufficient support to prevent bursting. Jennings (1995) concluded that extension in fungi is controlled by wall yielding processes and that these are likely to come about through an interplay of the cell wall and the cytoskeleton (Jackson and Heath 1990).

So, how do fungi grow? This is one of those compelling yet infuriating questions, the answer to which gets more complex the deeper we look. As is so often the case in science, complex questions are tackled using a reductionist approach. One consequence of this is that we often forget to apply our models or ideas to the bigger picture. We should thus be mindful that for the most part a fungus is not a single hypha but a collective, each constituent interacting with every other one. Such considerations may raise important new questions for mycologists to address.

Clipson, N. J. W. & Jennings, D. H. (1992) Dendryphiella salina and Debaryomyces hansenii: models for ecophysiological adaptation to salinity by fungi that grow in the sea. Canadian Journal of Botany 70: 2097–2105.

Garrill, A. (1995) Transport. In The Growing Fungus (N. A. R. Gow & G. M. Gadd, eds): 163–181. Chapman & Hall, London.

Gould, S. J. (1996) Dinosaur in a Haystack. Jonathon Cape, London.

Howard, R. J., Ferrari, M. A. Roach, D. H. and Money, N. P. (1991) Penetration of hard substrates by a fungus employing enormous turgor pressures. Proceedings of the National Academy of Science, USA 88: 11281–11284.

Jackson, S. L. and Heath, I. B. (1990) Evidence that actin reinforces the extensible hyphal apex of the oomycete Saprolegnia.ferax. Protoplasma 157: 144–153.

Jennings, D. H. (1995) The Physiology of Fungal Nutrition. Cambridge University Press, Cambridge. UK.

Kaminskyj, S. G. W. & Heath, I. B. (1996) Studies on Saprolegnia ferax suggest the general importance of the cytoplasm in determining hyphal morphology. Mycologia 88: 20–37.

Money, N. P. (1994) Osmotic adjustment and the role of turgor in mycelial fungi. In The Mycota. Vol. 1. Growth, Differentiation and Sexuality (J. G. H. Wessels & F. Meinhardt, eds): 67-88. Springer-Verlag, Berlin.

Money, N. P. (1999) On the origin and functions of hyphal walls and turgor pressure. Mycological Research 103: 1360.

Money, N. P. & Harold, F. M. (1993) Two water molds can grow without measurable turgor pressure. Planta 190: 426–430.

Picketts-Heaps, J. D. & Klein, A. G. (1998) Tip growth in plant cells may be amoeboid and not generated by turgor pressure. Proceedings of the Royal Society of London, B, 265: 1453–1459.

Rayner, A. D. M., Ramsdale, M., Watkins, Z. R. (1995) Origins and significance of genetic and epigenetic instability in mycelial systems. Canadian Journal of Botany 73 (Suppl. 1): S1241–SI248.

Ashley Garrill

Department of Plant and Microbial Sciences, University of Canterbury, Private Bag 4800, Christchurch, New Zealand. E-mail: a.garrill@botn.canterbury.ac.nz.

---

[2] See also 'Punching appressoria' in February's Mycological Research News (Mycological Research 104: 131–132, 2000).

FERTILISATION WITH AM FUNGI FAVOURS PARTICULAR TURF GRASSES

The links between mycorrhizal fungi and different plants are proving more intimate and complex than could have been foreseen a decade ago. Gange, Lindsay & Ellis (1999) sieved spores of arbuscular mycorrhizal (AM) spores from 18 putting greens and confirmed an earlier report by Gange (1994) of a negative correlation between the abundance of these fungi and the undesirable grass *Poa annua*. They also showed that the desirable *Agrostis stolonifera* predominated where AM fungal spores were most abundant.

A manipulative experiment took the process one stage further. AM inoculum was added to one green and the effects monitored. The results showed an increased colonization of roots of *Agrostis stolonifera* and an increase in the abundance of that grass on the green; the abundance of *Poa annua* was not enhanced, and there was some indication that adding inoculum could decrease the frequency of that species.

The actual assemblage of AM fungi involved six species of *Glomus* as well as some unidentified spores; the most abundant were *G. mosseae* (40%), *G. fasciculatum* (17%), and *G. intraradices* (14%).

The authors conclude that AM fungi have the potential to provide much more environmentally sensitive ways of controlling the frequency of the unwanted *Poa annua* in sports turf. A larger scale trial and commercial development will be needed before the method is widely used, but a new dimension of fungal biocontrol has been demonstrated.

Gange, A. C. (1994) Subterranean insects and fungi: hidden costs and benefits to the greenkeeper. In *Science and Golf II, Proceedings of the World Scientific Congress of Golf* (A. J. Cochran & M. R. Farrally, eds): 461–466. E. & F. N. Spon, London. [Not seen.]

Gange, A. C., Lindsay, D. E. & Ellis, L. S. (1999) Can arbuscular mycorrhizal fungi be used to control the undesirable grass *Poa annua* on golf courses? *Journal of Applied Ecology* **36**: 909–919.

WORLD CATALOGUE OF 340 K FUNGAL NAMES ON-LINE

The ideal of developing a comprehensive world catalogue of published names of fungi (including slime moulds, fungal protists, lichens, and yeasts) was developed at the then International Mycological Institute (IMI; now incorporated into CABI Bioscience) in the mid-1980s, and informally referred to as *Species Fungorum*. This was never conceived as a single project but as a long-term goal towards which several loosely related projects and initiatives contributed.

Names in fungal groups have been catalogued in a variety of printed works (Table 1), but since 1970 (when lichen-forming fungi were added) all are currently listed in the twice-yearly *Index of Fungi*. Accessing earlier names involved seeking out and checking a range of publications which are available only in a few mycological centres world-wide. The need was to convert the printed works into an open and generally accessible computerised database.

The start was the keyboarding of index cards with 32 000 names of fungi represented by material in the IMI reference collections; these names amounted to those for about 40% of the world's accepted species. A computerized production system for the *Index of Fungi* (published since 1940) was subsequently implemented in 1986. The issue was then how to incorporate data from earlier volumes of the *Index* and other printed catalogues. The 1980–86 *Index* data were keyboarded by the end of the decade, yielding a combined database of some 50 000 names. Fortuitously, the USDA's Systematic Botany and Mycology Laboratory in Beltsville was producing an index to the 26 volume *Sylloge Fungorum*, which covered names published up to 1920; this comprised about 120 000 names and was published on the internet and also as a book (Reed & Farr 1993). Access to a scanner and OCR software facilitated the capture of data from the various other cumulative indices. Resources were not available to capture this data in its entirety, but the indices were converted into an electronic format. The three *Index of Fungi* supplements were also captured in this way. All that was then missing was the names of lichen-forming fungi published before 1960; data from Lamb's *Index* covering 1932–60 and the cumulative index to Zahlbruckner's 10 volume catalogue were keyboarded and checked by the then Director and his son.

The major task of consolidation into a single database was then tackled. This was produced as two tables, the only concession to a relational structure being that titles of items of literature were stored separately to avoid problems with storage requirements. The whole was given the name of FUNINDEX (Fungus Name Index); a consequence of the old DOS 8+3 file naming convention. Basic data (name, author, year) from the database was later added to the TRITON 'universal name locator' system (ttp://www.york.biosis.org/triton/nameind.htm) managed by BIOSIS UK and loosely linked to the SPECIES 2000 project. This is a single system which includes the names of animals, mosses, bacteria, algae and fungi (names of plants are still absent from this system). Since January 2000, FUNINDEX can also be found through the following URL: http://194.131.255.3/cabipages/. There is no charge for access to FUNINDEX. However, access to the full data derived from recent issues of the *Index of Fungi* is restricted and only the basic information is available free in FUNINDEX; this action was necessary to protect the subscription base for the *Index* on which FUNINDEX depends for its maintenance and updating.

FUNINDEX includes some 300 K species names and 40 K infraspecific names. Amongst these are some duplicates that could not be easily or unambiguously identified by automatic means; the precise number of duplicates is unknown, but is

Table 1. Printed indexes of fungal species names.

Deighton, F. C. (1969) *A Supplement to Petrak's Lists* 1920–1939. [Index of Fungi Supplement.] Commonwealth Mycological Institute, Kew.

Hawksworth, D. L. (1972) *Lichens* 1961–1969. [Index of Fungi Supplement.] Commonwealth Mycological Institute, Kew.

Index of Fungi (1940 on) [Twice-yearly; cumulative indexes every 10 years.] CAB International, Wallingford.

Kirk, P. M**.** (1985) *Saccardo's Omissions*.[Index of Fungi Supplement.] Commonwealth Mycological Institute, Kew.

Lamb, I. M. (1963) *Index nominum lichenum inter annos* 1932 *et* 1960 *divulgatorum*. Ronald Press, New York.

Petrak, F. (1930–44) Verzeichnis der neuen Arten, Varietäten, Formen, Namen und wichtigsten Synonyme. *Just's Botanischer Jarhbucher* **48**(3), **49**(2), **56**(2), **57**(2), **58**(1), **60**(1), **63**(2). [Reprinted and index prepared by Commonwealth Mycological Institute, Kew.]

Petrak, F. (1950) *Index of Fungi* 1936–1939. Commonwealth Mycological Institute, Kew.

Saccardo, P. A. (1882–1931, 1972) *Sylloge Fungorum*. 26 vols. [Index by Reed & Farr (1993).] P. A. Saccardo, Padua; Johnson, New York.

Streinz, W. M. (1892) *Nomenclator Fungorum*. Gorischek, Vienna.

Zahlbruckner, A. (1921–40) *Catalogus Lichenum Universalis*. 10 vols. Borntraeger, Leipzig. [Reprinted by Johnson, New York.]

unlikely to exceed 10%. After this adjustment, this index now reveals for the first time that the actual number of names which exist for the known 75–100K described fungi is about 320 K. Previous lower estimates of this figure prove to have been conservative, for example the 250K mentioned by Hawksworth *et al.* (1995). The focus to date has been on names in the rank of species, and infraspecific taxa have not been covered in some of the datasets incorporated (e.g. in lichen-forming fungi). The main result is a universal name-checker, with regard to the spelling and existence of fungal species names. That this is available freely renders it a major reference tool for all mycologists. The issue of which names are actually in current use is not fully addressed, although some, for example those in use in the IMI collections, are flagged. Full synonymy within datasets contributing to the SPECIES 2000 initiative (http://www.species2000.org) are included for a small but increasing subset of FUNINDEX. Transforming the entire database into one with accepted names and synonyms, and completing the bibliographic and other data elements, remains a task for the future – a task in which it is envisaged that the mycological community at large will become involved by supplying missing information from their own databases.

Hawksworth, D L., Kirk, P. M., Sutton, B. C. & Pegler, D. N. (1995) *Ainsworth & Bisby's Dictionary of the Fungi*. 8th edn. CAB International, Wallingford.

Reed, C. F. & Farr, D. F. (1993) *Index to Saccardo's Sylloge Fungorum Volumes I-XXVI in XXIX* 1882–1972. Reed Library and Herbarium, Darlington, MD.

Paul M. Kirk

CABI Bioscience UK Centre (Egham), Bakeham Lane, Egham, Surrey TW20 9TY, UK.
E-mail: p.kirk@cabi.org

DEATH OF DAVID WOOD

It is with the greatest regret that we report the most untimely and tragic death of Professor David A. Wood, one of our Editors, on 22 February 2000. David was a leading authority on cultivated mushrooms and made a significant contribution to this journal as well as to the British Mycological Society and mushroom science internationally. His death is a great loss to mycology and his family. A tribute will appear in a forthcoming issue of *The Mycologist*.