Mycology Answers

To what extent does Fungal Activity contribute to the Processes of Decomposition in Soils and in Composts?

When we retrieve a rotten apple from the fruit bowl, or take some forgotten mildewed shoes from a plastic bag, we are reminded that fungi are agents of decay and decomposition! It is clear that in such a selective situation a fungus can quickly overrun a substrate and lead to its degradation. However, in the soil environment and in a garden compost heap, fungi must interact within a complex mixture of microbial species, including bacteria, actinomycetes and small invertebrates. In such sites fungi are part of a complex mixture of microbes and they function in various ways within those complex ecosystems.

Most of the decomposition within soils is of dead plant material. Leaves, twigs and woody stems contain large energy resources which are gradually released by microbial activity. Soluble components (simple sugars and storage materials) are utilised first and relatively quickly, followed by structural polymers (cellulose and hemicellulose) and then by more recalcitrant polymers and the materials complexed with them (lignin and lignocellulose). At first, microbial activity is high in such dead material but as the easily used components are depleted the rate of decomposition slows down and gives rise to humus. Humus is a complex and heterogeneous mixture of organic materials, formed from the constituents of plants and soil microbes which are most resistant to microbial degradation. There is however, turnover of humus in soils. Some stable components will have turnover times of 40-100+ years but other components do decompose more rapidly.

The initial degradation of plant materials is started by the original colonisers of that debris (pioneer colonisers) and may include surface dwelling fungi, bacteria and yeasts including saprophytes (e.g. *Trichoderma* spp., *Cladosporium* spp.), potential pathogens (e.g. *Fusarium* spp.) and also endophytes (e.g. *Acremonium* spp.) living within the tissues of the plant without causing the development of symptoms in that host plant. In a garden compost heap there will be a more highly concentrated volume of dead plant material than would normally occur in soils. However, the decomposition processes occurs in much the same way in either circumstance, although mediated by environmental influences (pH, temperature, moisture levels, etc.).

Initially in a compost heap bacteria and yeasts will proliferate most rapidly and will quickly utilise the soluble nutrients present. In so doing they generate heat, raising the temperature to 70 - 80°C in a few days. Thermophilic fungi proliferate in the heap until the temperature becomes too high (thermophilic fungi, e.g. *Aspergillus fumigatus*, *Mucor pusillus*, will remain active up to 60°C). At this stage in the decomposition processes fungi are relatively inactive since the temperature is too high for outgrowth and mycelia will be killed by the rising temperature. In compost the temperature will rise, and be maintained above 50°C, for several days. Many bacterial cells will also be killed and others (e.g. *Bacillus* spp.) will form spores to aid their survival. The fungi have a greater role in decomposition when the temperature begins to reduce following that initial burst of metabolic activity. Thermophilic species re-colonise when the heap temperature falls back to a more conducive level. Fungal species tolerant of the lower temperatures will germinate and grow out from spores. These species often have the capacity to rapidly and efficiently degrade cellulose (e.g. *Chaetomium thermophile*; *Humicola insolens*). Major components of plant cell walls are then removed from the compost, namely cellulose and hemicelluloses (arabinose, mannose, xylose). With further reduction in temperature, and the proliferation of other species, the degradation of recalcitrant polymers begins and lignocelluloses are gradually attacked by colonisers (e.g. *Fusarium* spp., *Coprinus* spp.). There are few soil microbes that can readily degrade lignin. The fungi are most instrumental in the degradation of truly woody materials although a few aerobic bacteria and some actinomycetes also have a role.

The growth and activity of species colonising dead plant material will be influenced heavily by

environmental variables. In addition to temperature, which fluctuates with microbial activity in a compost heap, moisture is essential. A supply of oxygen is required for the proliferation of decomposing fungi in a compost heap. If oxygen becomes depleted then lactic acid bacteria will proliferate, as in silage production, where these bacteria facultatively ferment sugars generating lactic acid and reducing the pH to about 4.0. The growth of fungi continues while oxygen is available. Nitrogen is also essential for composting although it is the proportion of carbon to nitrogen that is most important. Fungi convert carbon into material used for the construction of hyphal walls for their own proliferation and will quickly deplete nitrogen in the surroundings. Nitrogen is required for the production of enzymes and proteins. When nitrogen levels fall, then decomposition will cease even though there may still be sufficient carbon to support growth. Some fungi, in particular the wood decomposers, are able to recycle nitrogen by autolysis (self-digestion) of hyphae. Nitrogen is released from cell components in aged regions of the colony and this can be used to fuel further growth and activity in these species. If this process does not occur, or provides insufficient nitrogen, then further supplies must be obtained from elsewhere. In addition, as soluble nutrients are depleted, there will also be increasing competition and antagonism between species in the fight for nutrient resources. Some species, particularly potential pathogens, are not combative and do not compete well in such an environment. Others however, may be very aggressive and will attack and lyse neighbouring hyphae, even from a distance. Such activity may lead to rapid nutrient recycling between individuals.

Much degradation in compost heaps and in soils may be the result of cooperative processes. Activities of several neighbouring species, growing in fairly close proximity, may lead to a high level of degradation in some substrates, particularly those that are most recalcitrant. A single fungal species colonising a substrate may lack the enzyme capacity to fully degrade it and be able to only partially utilise that nutrient source. The enzyme activity of a neighbouring species may lead to further degradation at that site, a situation which would not occur if either species were growing alone. The activities of other soil microbes and invertebrates must also not be overlooked. Although few soil microbes can degrade lignin, attack by a range of enzyme activities will progressively cleave chemical bonds so that the materials are ultimately absorbed by one organism or another. Humus will be gradually utilised as a nutrient source by a succession of organisms and a battery of enzyme activities, whether it is in a compost heap or in the soil environment. Fungi have a key role to play in those decomposition processes.

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