Small molecule natural product from a fungus induces thermotolerance in plants

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The green cover on earth would not exist but for the plant roots being associated with fungi. A majority of these fungi have not been cultivated in the laboratory, hence their roles have been difficult to establish. For example, it has taken almost a century of researches to establish that the fine roots of virtually all plants are attached to fungi, called mycorrhiza. Their fine filamentous hyphae extend through a large area of soil, absorb nitrogen and phosphorus, and other scarce nutrients, and supply these to the plant in return for photosynthetically made carbon compounds. This plant–fungus symbiosis evolved approximately 400 million years ago. This is inferred from the finding in plant fossils of fungal spores that are similar to spores of the present day mycorrhizal fungi. All higher forms of life are directly or indirectly dependent on photosynthesis, in other words on plants.

Since plants are immobile, early in evolution, they must have also required a mechanism for adaptation and survival in environments that subjects them to wide variations in temperature, both seasonally and diurnally. For the plants growing in deserts, the problem of surviving high temperatures is more acute. This manifests in their morphology. They have reduced leaves to conserve water; or the stems are flattened and succulent to absorb and store water from the little rains it receives; or they have thorns to discourage a thirsty desert animal in search of liquid from nibbling, etc. Not visible to the naked eye are the fungi. From the rhizosphere of the Christmas cactus, *Opuntia leptocaulis* (Figure 1) growing in the Sonoran desert, in a recent study by the group of A. A. Leslie Gunatilaka[1] at the University of Arizona, the researchers isolated a fungus *Parasphaeospheria quadriseptata* (Figure 2). Rhizosphere is about 1 mm region of soil surrounding the roots. Liquid chromatography–mass spectrometry analysis of ethyl acetate extracts of this fungus led to identification of a secondary metabolite, monocillin (MON; Figure 3) comprising about 30% of dried extracts. Application of as low as 0.1 μM MON to seedlings of a test plant *Arabidopsis*, or cocultivation of the fungus with this test plant, enhanced its heat tolerance. For example, soil temperature in Sonoran desert can be 55°C at 1400 h at which time the leaf temperatures reach about 30°C. The seedlings of this 'model' plant die if exposed to constant 45°C for 50 or 75 min. It was suspected that MON application must trigger a heat shock response, which is mediated by a family of proteins called the heat shock proteins (HSPs). Some promote the degradation of misfolded proteins; others promote the activation of proteins already aggregated (as when denatured by heat), thereby preserving the three-dimensional structure (shape) of the cell's proteins, i.e. they are chaperone protein that prevents other proteins from taking conformations that would be inactive. The authors found that MON can interact with HSP90 – a conserved molecular chaperone that links to many proteins, including HSP101, allowing the plant to immediately recover from heat shock, and thereby increasing plant tolerance to heat stress that they otherwise would not survive. *Arabidopsis* mutant seedlings that lacked HSP101 did not survive heat stress.

This finding opens up 'many exciting new avenues of investigation'. Preconditioning crop plants by spraying, based on weather forecast, of fungal-derived natural product may be a new means of protecting crops by induction of HSP101 for protection against abiotic stresses. This study will undoubtedly stimulate interest in extending the isolation of new fungi from the rhizosphere of plants (where fungi are numerically more because of root exudates) growing in a variety of environment, their culturing, and screening natural products that induce HSP101 in test plants for protection from heat stress.

Figure 1. Christmas cactus (*Opuntia leptocaulis*). Courtesy: Dr Leslie Gunatilaka.

Figure 2. Fungus *Paraphaeospheria quadriseptata*. Courtesy: Dr Leslie Gunatilaka.

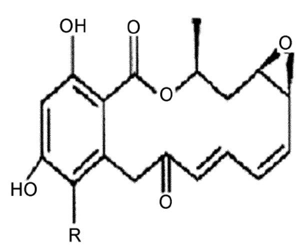

Figure 3. Structure of monocillin, R=H.

1. McCcLellan, C. A. *et al.*, *Plant Physiol.*, 2007, **145**, 174–182.

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