A Survey of Spore Ornamentation in Ectomycorrhizal Fungi – Is Ornamentation an Adaptation for Short Distance Dispersal?

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Abstract: Survey of spore ornamentation in basidiomycetous ectomycorrhizal fungi revealed that 70% of the species produced ornamented spores. Scanning electron micrograph study showed the possible evidence for the resistance, due to the presence of spore ornamentation, offered by ornamented spores against getting washed off by water, leading us to propose that ornamented basidiospores have advantage over their smooth-spored counterparts, the former adapted for short distance dispersal to retain the spores within the host range.
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1. Introduction

Ectomycorrhizal (ECM) fungi are known to form symbiotic association with roots of higher plants belonging to Betulaceae, Dipterocarpaceae, Fagaceae, Myrtaceae, Pinaceae etc., aiding in mutual benefits. World over a total of ~ 7750 species have been designated as ectomycorrhizal fungi (Rinaldi et al, 2008). Many of the fungi forming ECM association are known to occur in higher altitudes and move between of suitable habitats in disjoint patches; the basidiospores are carried by air flows and allow dispersal between patches. Components of animal kingdom are also known to aid in ectomycorrhizal spore dispersal (Lilleskov and Bruns, 2005). Our survey of ECM spore morphology revealed that many of the species forming ECM association had ornamented spores. These ornamented spores could hold on to the soil substratum thus, avoiding getting washed off in rain water and therefore most of the propagules of ECM fungi remain within the host range. We propose that the ornamentation with respect to the basidiomycetous fungi could have an advantage over their smooth-spored counterparts, the former adapted for short distance dispersal to retain the spores within the host range.

2. Materials and Methods

Survey of literature showed that 167 basidiomycetous fungi formed ectomycorrhizal association (Rinaldi et al, 2008). These fungi were checked for their presence/ absence of ornamentation with the help of description for fungi available in Mycobank (WWW.MYCOBANK.ORG) and for others a comprehensive literature survey was made.

For simulating a condition akin to the deposition of basidiospores in soil, the spores were mixed with talcum powder and scanning electron micrograph pictures were taken.

3. Results and Discussion

Our survey resulted in 7365 species of basidiomycetous ECM fungi, of which, 5123 species (70%) were found to produce ornamented spores and 2242 species produced smooth spores (Table 1 showing only those genera with 5 or more species). Although ornamentation in fungal spores have also been found in other basidiomycetous, ascomycetous and mitoporic fungi, here, we speculate the importance of ornamentation only with respect to the basidiomycetous ECM fungi. It is known that the basidiospores of epigeous basidiomycetes are dispersed by wind. Galante et al (2011) have shown that 95% of the basidiospores fall within 1 m of the cap. Further, in the case of spore dispersal by wind, surface ornamentations only mildly increase drag (Roper et al, 2008), suggesting dispersal by wind is effected in the smooth-walled and ornamented spores equally. This suggests that most of the propagules fall near the host in both smooth and ornamented–spore producing species. The ECM fruiting structures mainly occur during the period of precipitation when the conditions are favourable, and the propagules may also be washed off in rain water along with wind dispersal. But, if the spores are ornamented they could get entangled in soil particles (or pores in the soil particles) as shown with help of a simulated condition similar to that occurring in nature: We found that the ornamented spores cling on to the

Table 1. Fungal genera known to form ectomycorrhizal association

Ectomycorrhizal fungal genera[§]	No. of species reported*	Basidiospore ornamentation
Afroboletus	7	Ornamented
Albatrellus	16	Smooth
Alnicola	30	Ornamented
Alpova	20	Smooth
Amanita	500	Smooth
Amaurodon	10	Ornamented[@]
Amphinema	6	Smooth
Arcangeliella	12	Ornamented
Aureoboletus	5	Smooth
Auritella	7	Smooth
Austroboletus	30	Ornamented
Austrogautieria	6	Ornamented
Austropaxillus	9	Smooth
Boletellus	50	Smooth
Boletopsis	5	Ornamented
Boletus	300	Smooth
Byssocorticium	9	Smooth
Calostoma	15	Ornamented
Cantharellus	65	Smooth
Chalciporus	25	Smooth
Chamonixia	8	Ornamented
Chroogomphus	18	Smooth
Clavariadelphus	19	Smooth
Clavulina	40	Smooth
Coltricia	20	Smooth
Coltriciella	7	Ornamented
Corditubera	5	Ornamented
Cortinarius	2000	Ornamented
Cystangium	7	Ornamented
Dermocybe	15	Ornamented
Descolea	10	Ornamented
Destuntzia	5	Ornamented
Entoloma	100	Ornamented
Fistulinella	15	Smooth
Gallacea	5	Smooth
Gastroboletus	10	Smooth
Gautieria	25	Ornamented
Gloeocantherellus	6	Ornamented
Gomphidius	10	Smooth
Gomphus	10	Ornamented
Gymnomyces	37	Ornamented
Gyrodon	10	Smooth
Gyroporus	10	Smooth
Hebeloma	150	Ornamented
Heimioporus	16	Ornamented
Hydnum	120	Smooth
Hygrophorus	100	Smooth
Hymenogaster	100	Ornamented
Hysterangium	50	Smooth
Inocybe[#]	500	Ornamented
Laccaria	75	Ornamented
Lactarius	450	Ornamented
Leccinellum	5	Smooth
Leccinum	75	Smooth
Leucogaster	20	Ornamented
Leucopaxillus	15	Ornamented
Leucophleps	5	Ornamented
Lindtneria	11	Ornamented
Lyophyllum	50	Smooth
Macowanites	30	Ornamented
Malajczukia	8	Smooth
Melanogaster	25	Smooth
Multifurca	5	Ornamented
Naucoria	30	Ornamented
Octaviania	15	Ornamented
Paxillus	15	Smooth
Phellodon	16	Ornamented
Phylloporus	50	Smooth
Piloderma	6	Smooth
Pisolithus	12	Ornamented
Pseudotomentella	9	Ornamented
Pulveroboletus	25	Ornamented
Ramaria	220	Ornamented
Retiboletus	6	Smooth
Rhizopogon	150	Smooth
Rozites	20	Ornamented
Rubinoboletus	10	Smooth
Russula	750	Ornamented
Sarcodon	36	Ornamented
Scleroderma	30	Ornamented
Sebacina	6	Smooth
Setchelliogaster	6	Ornamented
Sinoboletus	5	Smooth
Stephanopus	5	Ornamented
Strobilomyces	20	Ornamented
Suillus	50	Smooth
Thelephora	50	Ornamented
Timgrovea	5	Ornamented
Tomentella	75	Ornamented
Tomentellopsis	5	Ornamented
Trechispora	46	Ornamented
Tremellodendron	8	Smooth
Tricholoma	200	Smooth
Tubosaeta	5	Smooth
Tulasnella	46	Smooth
Turbinellus	5	Ornamented
Tylopilus	75	Smooth
Xanthoconium	7	Smooth
Zelleromyces	17	Ornamented

[§] Rinaldi et al (2008); * Kirk et al (2008)

[@] One species smooth-walled.

[#] Pegler and Young (1972) reported small rugulosities under electron microscope in both smooth and nodulose-spored species of *Inocybe*, therefore, spore-wall of *Inocybe* have been considered ornamented.

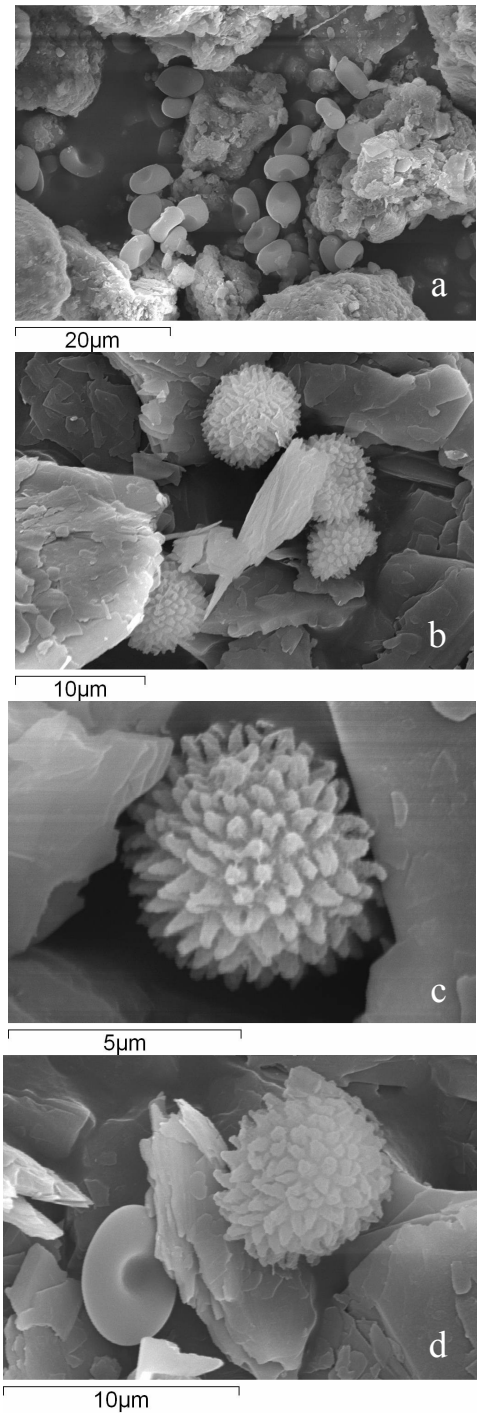

Figure 1. SEM photographs of basidiospores placed in talcum powder – a condition similar to that of spores present between soil particle or in soil pores. **a**. Basidiospores of smooth-walled agaric occurring between particles, **b.** & **c.** Ornamented basidiospores of *Pisolithus arhizus* (Scop.) Rauschert seen entangled between particles of talcum powder, **d**. Comparison of both smooth-walled and ornamented spores together.

talcum powder particles (Figure 1a-d), but smooth-walled spores get simply placed in the spaces between particles, thus making them vulnerable to running-off with the stream of water. We opine that spore ornamentation is an important adaptation for dispersal within host range/host population since the fruiting structures are formed (and they mature) during rainy period and dispersed/washed along with rain water, in the sloppy terrain, that can carry the spores to long distances if there is no resistance provided by the spores ultimately taking them out of the host range (a wastage of energy). Thus, we propose that ornamentation of basidiospores could have advantage, especially with respect to adaptation for short distance dispersal. Hibbett et al (2000) after studying 161 species for their nuclear and mitochondrial rDNA opine that some of the homobasidiomycetous ectomycorrhizal forms have reversed to free living saprophytic forms and suggesting that mycorrhizae are unstable dynamic association. But, their results show that these reversals have mainly occurred with respect to groups forming smooth walled basidiospores. Further, *Amanita muscaria*, producing smooth basidiospores, forms association with more than 20 species of host plant (Trappe, 1962; Hibbett et al, 2000), showing wider host adaptability (probably conferred by ability for long distance dispersal due to the presence of smooth spores). Observation made by Vellinga et al (2009) that introduced species of ectomycorrhizae appear to be constrained from spreading to novel habitats and associate only with their introduced hosts, could be a support to our proposal.

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