DIVERSITY OF FRUITING PATTERNS OF WILD BLACK MOREL MUSHROOM

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ABSTRACT

Morels (*Morchella* spp., Pezizales) are commercially important edible mushrooms, known for their delicate taste and aroma, which mostly reach the market from growth in the wild. However, despite their high market value, knowledge of morel behavior in its natural habitat and of the fruiting patterns exhibited by the various species in different habitats is scarce. Morels are found worldwide in a range of natural habitats, and many reports have linked morel fruiting with extreme changes in the environment, including deforestation, soil dryness, heavy rains, pesticide application, etc. Knowledge of morels' fruiting patterns in nature is needed for both conservation practice and to increase the value of non-timber forests. We located several distinct populations of black morels growing in different habitats, and monitored their population dynamics to define their fruiting patterns. Based on molecular identification, the mushrooms of the different black ecotypes belonged to *Morchella* species *conica* and *elata*. Each of these species exhibited more than one fruiting pattern, affected by both spatial heterogeneity of the growing site and climatic conditions, as will be discussed in the presentation.

Keywords: *Morchella*; Morel; Fruiting pattern; Mushrooms; Forest management

INTRODUCTION

Morel mushrooms (*Morchella* spp., Pezizales, Ascomycetes) include a range of species growing in temperate zones throughout the world—the Asian and Himalayan mountains, European and Mediterranean countries, and the Americas, from Alaska to Mexico. Due to high market demand for these delicate mushrooms, they are harvested in commercial quantities from certain locations for global supply, highlighting the need for a better understanding of factors affecting morel fruiting in the wild. Moreover, overharvesting of mushrooms in general has raised concern about forest health, as well as about the decline in morels [1]. Although in recent years, there has been an increase in studies focusing on morel biological and ecological features [1-4], knowledge of its behavior in natural habitats is still scant. Understanding phenology and spatial distribution of the mushroom population in forests or other habitats is important for both conservation policies and for increasing the value of non-timber forest products.

The morel's general life cycle was tentatively described by Volk and Leonard [5]. However, there is still much to learn with respect to the complexity of the morels' distribution due to the high diversity of habitats in which they grow, high polymorphism in head shape and color [6,7], and high genetic variation [8]. The issue is further complicated by their undefined trophic state: some are presumably mycorrhizal, while others are free-living [9]. Confusing reports in the literature make it difficult to follow the morels' natural population dynamics or growth patterns in natural heterogeneous environments, and to relate certain ecological behaviors to particular species. To study the fruiting pattern of wild morels, it is necessary to locate morel patches as soon as they emerge. This is a difficult task, as in many cases morels appear in unexpected locations, and then only for short periods.

In recent years, we have studied the diversity of morels in Israel, where they are considered rare. As in other places in the Mediterranean region, in Israel, both yellow and black morel mushrooms have been observed [3, 4 10, 11]. We have observed morels in a range of habitats, including a natural Mediterranean grove, a forest after a fire, residential yards, waste-disposal sites and more. A similar range of habitats is known for morels in other parts of the world where they are found near healthy vegetation or in disturbed soil. In most cases, morels are detected only in their mature state, and there are only a few of them. This has made it difficult to study fruiting patterns of the different populations. Nevertheless, we were able to spot a few patches of morel populations in their early stages of emergence, and to follow their growth over a season or more [3].

Here we describe the different fruiting patterns of two distinct populations of black morels located in their early stage of emergence. While both fruited in early spring, they grew in different habitats, and exhibited different fruiting behavior.

MATERIALS AND METHODS

Morel populations and field characterization. Fruiting bodies of the different populations of black morels were located in five different habitats in Israel in the year 2006: in a post-fire forest, a residential backyard, along asphalt pavement, and at two sites in a healthy, undisturbed Mediterranean forest. The post-fire population and the Mediterranean forest populations were spotted at first fruiting body emergence, and their spatial and temporal fruiting patterns were monitored. The fire at the post-fire forest site occurred in the summer of 2006, and the burnt forest was under heavy forest management. All habitats were characterized according to dominant plantations, general soil type and environment (Table 1). Fruiting was monitored throughout the 2006-2007 season and in the following 2 years.

Molecular identification of morel species. Molecular identification of the black morels was performed on mycelial culture isolated from each of the defined (according to growing site) populations [4]. DNA was extracted by phenol/chloroform procedure from the freeze-dried mycelial biomass of each isolated strain. The internal transcribed spacer (ITS) region of its nuclear ribosomal DNA (nrDNA) was analyzed according to Wipf et al. [12] by PCR amplification using ITS1/ITS4 primer pairs and sequencing. The sequences of the local black morels were compared to those of reference *Morchella* strains obtained from DSMZ (The German microbial collections).

Climate data. Data on rain events were obtained from a meteorological station located 5 km from the burnt forest site.

RESULTS AND DISCUSSION

Black morel species and habitats. Distinct populations of black-headed morels were observed in 2006 in a range of sites across Israel. The sites varied in nearby vegetation, especially in dominant tree species, the soil surface on which the mushrooms appeared and the environment (disturbed or pristine) (Table 1). Head polymorphism was observed within each site's population with a variety of color nuances, ridge arrangements, head and strip ratios and head thicknesses.

The black morel species of all distinct populations were identified using a molecular, rather than morphological approach. In recent years, there has been an increase in studies using molecular tools for morel classification [12]. Here, molecular identification of the different populations was based on use of the ITS1/IT4 primer set to obtain the ITS region sequence (nrDNA). A comparison of the sequences from the different black morel populations to reference *Morchella* strains obtained from DSMZ (German) revealed two species, *M. conica* and *M. elata*. Molecular identification showed that all black morels found in the disturbed sites (i.e. post-fire forest, pavement and disturbed residential soil) were *M. conica* Pers (=*M. Vulgaris* (Pres) Boud). In general, these sites were near pine trees. It is assumed that these sites enjoyed a nutrient boost during the soil-disruption event, enabling the morel mycelium to gain biomass and fruit. *M. elata*, on the other hand, grew in the non-disturbed oak forest, on litter-rich soil beneath the trees, or on the surface of chalk rocks in a shaded area. It is assumed that this ecotype grew in association with the plantation, i.e. was dependent on nutrients released from the vegetation, mainly the oaks.

Table 1: Characterization of morel species and their habitats

Ecotype	Morel species	Habitat	Dominant plants	Growing surface
MS790	*M. conica*	Post-fire forest	Pine (*Pinus halepensis*)	Soil with burnt debris
MS782	*M. conica*	Disturbed soil in residential backyard	Grass, pine (*Pinus halepensis*)	Mixture of gravel and sand
MS765	*M. conica*	Roadside	Healthy pine (*Pinus halepensis*)	Asphalt pavement
MS807	*M. elata*	Mediterranean grove	Oak (*Quercus calliprinos*)	Chalk rock covered with moss
MS794	*M. elata*	Mediterranean grove	Oak (*Quercus calliprinos*)	Heavy organic soil with high litter content

Spatial fruiting patterns. Spatial distribution of the mushrooms at each site was influenced by the spatial heterogeneity of disruptive factors and food sources. In the post-fire forest, forest-management activity affected the distribution of the morel ascocarps [3], with two main fruiting patterns observed. In one type of fruiting pattern, the morels emerged in a straight line. In the second, ascocarps were distributed over a wide area of the burnt site with no defined order. While the straight-line pattern was found along piles of burnt tree debris which had been lined up by forest personnel, the undefined distribution pattern was found in a wide, open area in which the burnt tree debris had been dispersed, with mushrooms appearing all across this area. In the post-fire forest, morels appeared in both sunny and shaded open spaces.

Morchella elata mushrooms appeared near healthy oak trees in undisturbed soil. Two distinct fruiting patterns were observed here as well. In one, morel mushrooms were distributed across a wide forest soil surface area at an average of 1 fruiting body per 10 m^2, mostly singly. The second pattern was emergence of several patches of dense morel populations on the surface of chalk rocks at 2 to 5 morels per 0.5 m^2. In all *M. elata* cases, while morels grew in open spaces 2 to 5 m from the tree trunks, most of the time they grew in shaded areas.

Temporal fruiting patterns. In the burnt forest, high quantities of morels appeared in the first year after the fire, with amounts declining over the next 2 years of field inspection. Two waves of mushroom emergence were detected for this ecotype in the first year: the first peaked in early March (on 2 March only a few mushrooms were observed, on 7 March, there was a high peak, followed by a decline observed on 20 March); on 20 March, a new wave emerged in another area of the same burnt forest. No re-growth of black morels was seen in the soil that supported the first growth wave. The second wave peaked at the end of March/early April. Fruiting events of *M. conica* in the post-fire forest were correlated with rain events (Fig. 1). The first wave of mushrooms emerged after heavy rains in February and disappeared within 3 weeks. The second wave appeared after a second wave of heavy rain in early March followed by a few dry days.

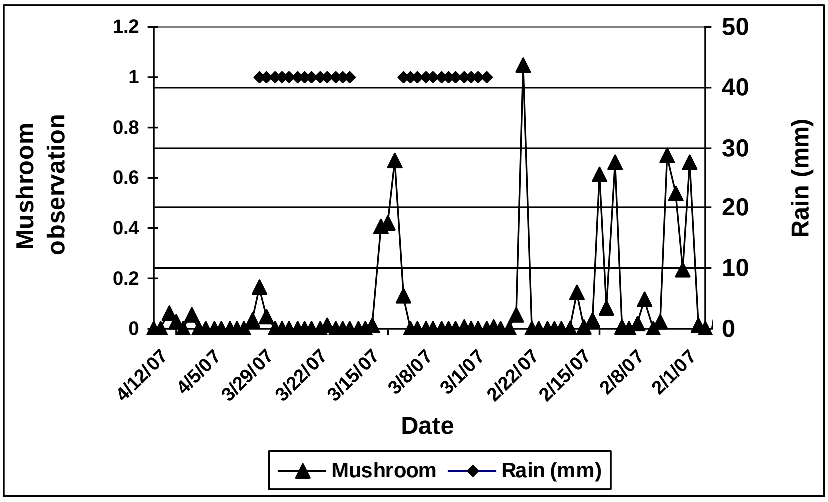

Figure 1: Rain profile during the winter of 2006-2007 and *M. conica* fruiting in the post-fire forest

For *M. elata*, only one major fruiting wave was detected, but the number of fruiting bodies increased gradually, such that they were observed at the site for almost 6 weeks. Unlike the *M. conica* ecotype, the *M. elata* population was stable over the years and was spotted each year at the same site, in the same soil.

The other *M. conica* ecotypes, found in the residential yard and along the pavement, were spotted only in their mature state, with only a few in each habitat. Therefore, it was not possible to study their fruiting patterns. Similar to the post-fire ecotype, these mushrooms disappeared from the site in the following year. We concluded that the *M. conica* morels that fruited in disrupted soil have no nutrient reservoirs to support their fruiting in a second or third season at the disturbed site. They are opportunistic and appear for only one season. In contrast, the *M. elata* ecotype probably has some relationship with the surrounding live vegetation, which affords it a continuous supply of nutrients, enabling it to fruit at the same site for many years.

Temporal fruiting pattern in morels has been shown to be controlled by climate or other seasonal conditions. Buscot [9] reported that *Morchella rodundra* fruiting-body emergence in France is controlled by soil temperature degree-days. Rain has been found to be a key factor in the emergence of morel fruiting bodies [1]. In the post-fire site, while fire enhanced fruiting-body emergence, the timing of their emergence was related to precipitation.

CONCLUSIONS

Morels show a variety of fruiting patterns. While these are dependent on the morel species or its trophic state, they are much more dependent on the heterogeneity of the habitat. In the post-fire forest, management by forestry authorities affected the dispersal of the mushrooms, which were either distributed over a wide area where the burnt wood debris was spread over the forest soil, or concentrated near piles of burnt debris. Here we present a few ecotypes of *M. conica* and *M. elata*. More work is needed to define the temporal and spatial fruiting patterns of the different species and their ecotypes on a global scale, to gain a better understanding of the morel's complex life cycle.

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