More mushrooms under a full moon – myth or reality?

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Forest mushrooms not only have important functions within the forest ecosystem, picking the edible ones is a popular pastime for many people and an important commercial activity in many regions of the world. The formation of basidiomata is complex and has been the subject of legends and myths. One of these is the popular belief that mushroom harvests at full moon are particularly rich. Here we examine a total of 1715 dated mycological records, collected between 1990 and 2007 in five long-term observation plots in Switzerland to test for a possible relationship between lunar periodicity and mushroom yields. No such relationship was found, which means the claim that the moon phase influences mushroom production is based on myth.

Keywords: basidiomata, lunar cycle, mushroom yields, myth, wild forest mushrooms

Forest mushrooms are important in forest ecosystems, acting as mycorrhizal symbionts, decomposers, and pathogens (Dighton *et al.* 2005). Picking their edible basidiomata is a popular pastime and a recreational activity in many countries (Boa 2004). Some mushrooms are of special economic interest, such as truffles (*Tuber* sp.), the king bolete (*Boletus edulis* Bull.), chanterelles (*Cantharellus* spp.), or the matsutake mushroom (*Tricholoma matsutake* [S. Ito & S. Imai] Singer). It is therefore of great interest to learn more about factors which influence or determine their appearance and yield. Weather conditions highly affect mushroom growth: temperature and water availability are key factors for basidioma formation (Krebs *et al.* 2008), but they do not entirely explain mushroom occurrence (Straatsmadee *et al.* 2001, Barroetavena *et al.* 2008, Krebs *et al.* 2008). Due to the relatively poor level of knowledge about the mechanisms of basidioma production of wild forest mushrooms, legends and myths about mushroom growth abound. One popular folk tale says that the mushroom harvests are particularly rich at full moon. In fact, the periodic waxing and waning of the moon has given rise to many claims about how the lunar cycle affects plant growth and animal reproduction (Zanchin 2001). Looking through the corresponding scientific literature, we notice that the majority of studies do not confirm such a relationship and there are only a few scientifically proved effects of the lunar cycle on living organisms and their behavior. They mostly concern secondary effects of the lunar cycle, such as varying light conditions or gravity and tide effects (Gliwicz 1986, Rahman *et al*. 2004, Yamamoto *et al*. 2008), or nocturnally active animals (Lang *et al*. 2006, Deeming 2008, Grant *et al*. 2009).

There are some scattered results which found significant relationships between the lunar cycle and human biology: gout attacks are highest under the new and the full moon (Mikulecky & Rovensky 2000), and the number of sudden unexpected death in epilepsy was shown to be highest during full moon (Terra-Bustamante *et al*. 2009). Beyond that, however, there is no solid scientific evidence for other effects of the lunar cycle on human behavior (Zanchin 2001, Foster & Roenneberg 2008). Contrary to popular belief, the frequency of human births is not higher around full moon than on other days, and neither is the percentage of complications nor does the lunar cycle influence the gender of newborn babies (Waldhoer *et al*. 2002, Arliss *et al*. 2005, Morton-Pradhan *et al*. 2005, Staboulidou *et al*. 2008).

Although there is a wide range of observations of lunar influences on plants (Endres & Schad 2002), scientifically proved effects are very rare in this field as well. A popular belief is the importance of the lunar cycle for the planting and harvesting time of vegetables (Crawford 1989). Again, these theories are scientifically most controversial.

Zürcher *et al*. (1998) found a correlation between fluctuations in the diameter of tree stems of two Norway spruce trees grown in containers at a controlled temperature in continuous darkness, and the timing and strength of tides. They suggested that the moon influences the flow of water between different parts of the trees. These results were later challenged by Vesala *et al*. (2000) who did not find any correlation in an own study on trees growing in natural conditions in Finland and Scotland. They concluded that it was unlikely for the fluctuations observed by Zürcher *et al*. (1998) to have been caused by gravitational signals.

Zürcher (2001) strengthened the importance of the felling date for the wood properties in the context of the lunar cycle. According to his observations “full-moon-wood” is lighter and less durable than “new-moon-wood”. In a second study Zürcher *et al*. (2010) detected slight but significant lunar phase correlated variations in the drying behavior of Norway spruce [*Picea abies* (L.) H. Karst.] and Sweet Chestnut (*Castanea sativa* Mill.).

How about mushrooms? The research to date on a possible relationship between the lunar cycle and mushroom growth is again controversial. Hirschmann & Hirschmann (2000) analyzed 1800 dated mushroom consultation protocols at official mushroom control sites over a period of 32 years and detected a sinusoidal trend in the number of consultations as well as in the number of basidiomata, corresponding to the lunar cycle. Based on their results, they concluded that there was a clear correlation between the lunar cycle and mushroom yield. A re-analysis of the same data by Guiard (2002) revealed that these effects were either artifacts resulting from smoothing procedures or caused by human mushroom collecting habits. Other observations and data examinations could not prove any effect of the lunar cycle on basidioma occurrence (Kegel 2000, Richter 2006, Schopfer 2006, Halbwachs 2008). However, these studies are mostly based on personal opinion or unsystematic observation. For example, the data may have been collected at irregular intervals or with different intensity levels. Such methodological flaws mean that this research was not based on stochastically independent analysis, and the conclusions are therefore open to dispute.

The data set for the present study was, in contrast, collected systematically by one mycologist and standardized with one extensive inventory per week. We were thus able to analyze a total of 1715 mycological records, collected between 1990 and 2007 in five long-term observation plots in Switzerland, to see whether mushroom abundance differed according to how long after the new moon the inventory was recorded. Because of the postulated evidence that tree growth varies with the lunar cycle (Zürcher *et al.* 1998, Zürcher 2001, Zürcher 2010) we tested the mycorrhizal species separately. Their symbiotic dependence on trees may indirectly make them more susceptible in this regard than saprobic mushrooms.

Materials and methods

Study sites

Mycological data was collected in five long-term observation plots in western Switzerland. Details about the sites and the size of the inventory plots are given in Table 1.

Sampling

Between 1990 and 2007 the basidiomata of the epigeous macromycetes of soil-inhabiting fungal species were identified and counted once per week, from May to December (weeks 21–52) on the permanent observation plots (Table 1). When first recorded, the basidiomata were marked with methylene blue on the cap to avoid double counting. Each entry in the data set includes the date, the species name, the corresponding number of basidiomata, and the affiliation of the species to the ecological grouping of mycorrhizal or saprobic.

Table 1. – Site characteristics of the five study plots.

Site parameters	Chanéaz	Parabock	Moosboden	Pfynwald	Buron
Coordinates	N46°47'58'' E07°00'04''	N46°41'28'' E07°14'10''	N46°41'42'' E07°14'16''	N46°18'03'' E07°36'40''	N46°41'11'' E06°37'03''
Elevation (m a.s.l.)	600	1350	1200	600	500
Forest type	mixed forest	pure forest	pure forest	pure forest	pure forest
Tree species	mixed*	*Picea abies* (L.) Karst.	*Picea abies* (L.) Karst.	*Pinus sylvestris* L.	*Picea abies* (L.) Karst.
Tree age (years)	150	40	120	100	30
Precipitation (mm $year^{-1}$)	980	1250	1250	600	850
Soil type	calcaric cambisol	dystric gleysol	dystric gleysol	calcaric regosol	calcaric cambisol
Observed period	1992–2007	1994–2007	1990–2000	2003–2007	2000–2003
Size of inventory plot (m^2)	1500	1100	2366	1200	3000

* *Fagus silvatica* L., *Quercus robur* L., *Picea abies* (L.) Karst., *Abies alba* Mill., *Pinus sylvestris* L., *Pinus strobus* L., *Larix decidua* Mill.

Data analysis

We compared the number of basidiomata collected with the synodic lunar rhythm, first according to a binary variable (moonh1): 0 for day 1 to 14 (waxing moon) and 1 for day 15 to 29 (waning moon) to test whether basidioma production differs between the waxing and the waning moon. We then tested whether more mushrooms are produced around full moon than in other periods (moonh2), according to a variable coded 0 for day 1 to 10, 1 for day 11 to 20 (period of full moon) and 2 for days 21 to 29. The synodic cycle (full moon to full moon) has an average length of 29.531 days. Since the synodic month is slightly shorter than the mean calendar month, one calendar year comprises 12.4 lunations.

The null-hypothesis was that there is no correlation between the lunar cycle and the quantity of basidiomata of forest mushrooms. The Kruskal-Wallis test was used for statistical analysis with the statistical software R (R Development Core Team 2007). As a variable we used the square root of the total number of fungal basidiomata recorded on a single date, divided by the number of days since the last data entry to obtain a standardized number of fungal basidiomata per day. The tests were performed for each site separately, for all sites together, for the two ecological groups of mycorrhizal and saprobic species separately, and for all species together.

In the inventory we considered the visible basidiomata occurring at a specific date. To find out whether the initiation of the basidioma formation was influenced by the lunar cycle, we time-shifted the original data by subtracting five days from the original date. This corresponds to the estimated mean time needed between basidioma initiation and the appearance of a detectable basidioma.

Results

A total of 1715 calendar entries were analyzed. The data points are evenly distributed over the whole length of the lunar cycle and no relationship was found between the abundance of basidiomata and the phase of the moon: neither at full moon nor during a waxing or waning moon more basidiomata are produced than during other moon phases (Figure 1). Mycorrhizal and saprobic species do not differ in their behavior and the results apply to each of the five sites, as well as to all sites together. The p-values generated by the test are far away from significance thresholds (Table 2). Again, no influence of the lunar cycle could be detected in the time-shifted data, as compared to the original data.

Within the lunar cycle the data points are uniformly continuous on the time axis; the weekly intervals of the inventories have been smoothened out by the years of observation (Fig. 1).

Table 2. – p-values of the Kruskal-Wallis test for the two hypotheses: moonh1, to compare the period of the waxing moon (days 1 to 14) with the period of the waning moon (day 15 to 29), and moonh2 for testing whether basidioma growth is higher in the period of full moon (days 11 to 20) than in the other two periods (days 1 to 10, days 21 to 29). The first value refers to the original data, the second value to the time-shifted data (original date minus five days, corresponding to the estimated initiation of basidioma formation).

Moon period	Eco-groups	Chanéaz	Parabock	Moosboden	Pfynwald	Buron	All sites
Number of entries		743	387	325	135	125	1715
Moonh1	Mycorrhizal	0.34/0.66	0.69/0.90	0.62/0.67	0.75/0.86	0.51/0.68	0.55/0.63
	Saprobic	0.99/0.79	0.73/0.85	0.92/0.38	0.25/0.81	0.73/0.75	0.63/0.51
	All species	0.66/0.65	0.79/0.99	0.80/0.42	0.53/0.89	0.68/0.82	0.69/0.48
Moonh2	Mycorrhizal	0.78/0.71	0.57/0.58	0.92/0.92	0.70/0.86	0.71/0.53	0.69/0.78
	Saprobic	0.87/0.78	0.43/0.84	0.93/0.68	0.24/0.68	0.83/0.51	0.72/0.64
	All species	0.83/0.87	0.41/0.92	0.96/0.87	0.44/0.83	0.85/0.49	0.72/0.83

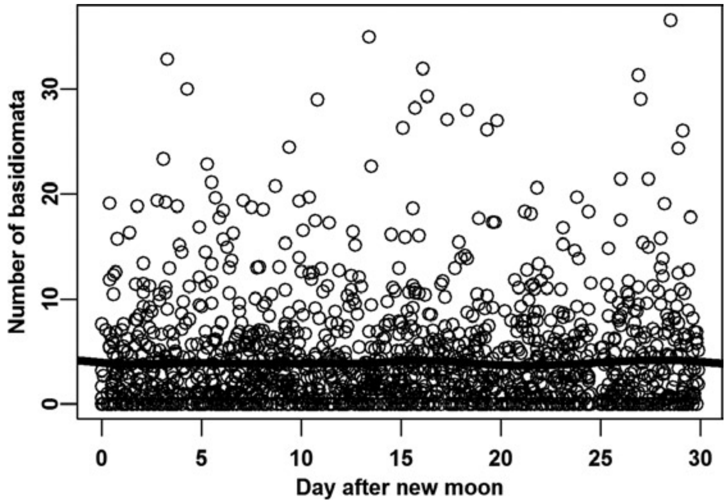

Fig. 1. – Mycological records (1715 entries) collected between 1990 and 2007 in five long-term observation plots, arranged according to their temporal position within the lunar cycle. The y-axis gives the standardized numbers of basidiomata per day (details see chapter Data analysis). The solid line represents the mean curve of the basidiomata data.

Discussion

The analysis of our data set clearly reveals that forest mushrooms grow independent of the moon phases. Neither the initiation of basidioma formation (time-shifted data) nor the occurrence of fully developed basidiomata (original data) is in any way influenced by the lunar cycle. Are our results universally valid or is their validity limited to Switzerland? If we assume that any effects of the lunar cycle on mushroom growth is caused by physical forces, i.e. by the moon exerting varying gravitational signals, it could be argued that these signals will not have a uniform impact over the whole globe, as, the gravitational pull of the moon differs between the equator and the poles. However, the resulting maximum spatial distance (equivalent to the earth's radius) is negligible proportional to the overall distance between the earth and the moon.

Our results coincide with the available published information on a possible relationship between the lunar cycle and mushroom growth. Kegel (2000), Richter (2006), Schopfer (2006), and Halbwachs (2008) conclude from their observations that mushrooms seem to grow independent of the lunar cycle. Hirschmann & Hirschmann (2000), however, claimed a positive correlation between the lunar cycle and mushroom yields; their results and conclusions were later proved wrong following a re-analysis of the original data by Guiard (2002).

The current state of knowledge indicates that the influence of the lunar cycle on biological processes is restricted to the strength and direction of magnetic fields at different positions throughout the lunar cycle, or to varying light conditions. Thus, marine organisms are affected by varying tides, as shown for zooplankton (Gliwicz, 1986), fish (Rahman *et al.* 2004), or seabirds (Yamamoto *et al.* 2008), and nocturnally active animals react to the moon-induced varying light conditions, for example bats or katydids (Lang *et al.* 2006) or newts (Deeming 2008) and other amphibians (Grant *et al.* 2009). These animals are more active during the dark period associated with the new moon compared to bright periods around the full moon. This is mainly a result of the predator-prey relationship. Furthermore, the incidence of animal bites to humans was proved to be higher during full moon (Bhattacharjee *et al.* 2000), and a significant increase in emergencies for cats and dogs was detected around full moon compared with all other days of the lunar cycle (Wells *et al.* 2007).

Scientific evidence for other effects is lacking. Many claims have nevertheless been made about the influence of the lunar cycle, leading to popular beliefs that are hard to dispel, as in the belief in a correlation between the full moon and the birth rate. If you ask a nurse, she will most probably agree that the number of births increases around full moon. Sixty-eight percent of consulted nurses working at obstetric clinics believed that labor is more likely to start during a full moon (Schaffir 2006). Although there are a few papers supporting this belief (Menaker & Menaker 1959, Guillon *et al.* 1988, Ghiandoni *et al.* 1998), many papers later rejected the hypothesis (Waldhoer *et al.* 2002, Morton-Pradhan *et al.* 2005, Arliss *et al.* 2005, Staboulidou *et al.* 2008). Moreover, two reviews of birth rate patterns both conclude that there is no evidence of such a relationship and that the few positive studies are inconsistent in their findings (Kelly & Martens 1994, Kuss & Kuehn 2008). Thus, the postulated effect of the moon on birth rates seems likely to be a myth. Nevertheless, popular belief is tenacious, and very difficult to refute, as is the case with most mythologies "passed down through oral tradition to an audience eager to impose order on a system that in fact operates randomly" (Schaffir 2006). Similarly, the popular belief in an effect of the lunar cycle on mushroom growth and yields seems to be a myth which is extremely difficult to dispel. But to be truthful, we must be ready to admit that most aspects involving the growth process of wild mushrooms are still not entirely understood, despite the fact that great progress has recently been made in identifying genes, proteins and enzymes contributing to basidioma initiation (Kues & Liu 2000, Wösten & Wessels 2006). This knowledge, however, is still restricted to selected model organisms that are accessible to molecular genetics and cannot be offhandedly applied to wild mushrooms. There is scientific evidence that forest mushroom growth is influenced by forest tree growth (Egli *et al.* 2010), due to the fact that most forest mushrooms are mycorrhizal fungi living in a mutual symbiosis with forest trees. They depend on photosynthetically fixed carbon produced by the associated host trees to extend their vegetative mycelium in the soil and to form basidiomata.

Our research indicates that the moon cycle has no effect on mushroom growth. Despite this evidence, many people will continue to believe in a relationship between the lunar cycle and biological processes like mushroom growth.

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