



Short communication

## A search for naturally grown Burgundy truffles (*Tuber aestivum*) in hazelnut plantations in Germany: Results of a survey

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### Abstract

To overcome the increasing strain on agricultural crop production in Central Europe, new management practices are in demand that allow for sustainable farming systems while providing the farmers with a reliable income. One option is the establishment of hazelnut plantations (*Corylus avellana*) to produce and sell hazelnuts. A possibility to further increase benefits from hazelnut plantations might be offered by harvesting summer truffles (or Burgundy truffles, *Tuber aestivum*), a species that frequently forms mycorrhizae with hazelnut trees in the wild. Consequently, a first systematic survey was undertaken to assess the potential presence of naturally grown *T. aestivum* on 14 existing hazelnut plantations in Germany using trained truffle dogs. Naturally grown Burgundy truffles were not found on the visited plantations. The dogs unearthed eight other species of hypogeous fungi. Hazelnut farmers should not be too optimistic that naturally grown *T. aestivum* will provide them with a noteworthy additional income from their plantations.

### Introduction

Bio-economic activities in Central European rural areas suffer from the increasing strain of agricultural crop production. Typically, this results in intensified management practices that often lead to declining biodiversity and reduced ecosystem services (Benton et al., 2003; European Academies Science Advisory Council, 2009). Hence, new agricultural practices are in demand that allow for sustainable farming systems while providing the farmers with a reliable income. Some of these approaches comprise the growth of perennial woody crops such as willow and poplar for energy consumption (Huber et al., 2016). Other approaches pursue the renewed and refined management of trees in agricultural land via the establishment of agroforestry systems, including the production of valuable timber for the veneer industry (Morhart et al., 2014). Another pathway of utilizing ecologically valuable crops is hazelnut tree plantations (*Corylus avellana* L.) to produce and sell (bio-) hazelnuts. At present, most of the hazelnuts processed and consumed in Central European countries such as Germany are imported from Mediterranean countries, especially from Turkey. Still, hazelnuts produced on a local or regional scale are preferred by intermediaries and consumers in Germany (Stobbe, 2017a) where approximately

300 ha of hazelnut plantations have been established since 2000, and the interest of farmers to establish further plantations is increasing despite management difficulties mainly concerned with the available harvesting methods (Stobbe, 2017a).

A possibility to increase the benefits from hazelnut plantations is the cultivation of truffles that form a mycorrhiza with hazelnut trees, specifically the summer truffle or Burgundy truffle (*Tuber aestivum* syn. *T. uncinatum*, Wedén et al., 2005). In fact, an increasing number of hazelnut seedlings inoculated with this truffle species are produced and sold for truffle cultivation, even in Germany; however, these seedlings are only designed to produce truffle ascocarps, and the quality and quantity of their nuts is negligible and irrelevant for commercial purposes (Chevalier and Frochot, 1997). On the other hand, young hazelnut plants for the establishment of hazelnut plantations are typically not colonized with truffle mycelia and these plants are grown via vegetative propagation methods, but since this is not conducted in a sterile manner, their roots are usually colonized by other mycorrhiza fungi species (Stobbe, 2017b). The production of hazelnut plants that produce both nuts and truffles is labor-intensive and thus, expensive. So far, their cultivation has not been realized in practice on a commercial scale, and if such seedlings were available, it would still be doubtful if farmers would invest a considerable amount

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of money to establish plantations with them for commercial purposes. Yet, because *T. aestivum* is a common mycorrhiza partner of hazelnut trees and is frequently found under wild hazel shrubs in Germany (Stobbe et al., 2012), it might colonize existing hazelnut plantations naturally, as it has invaded other plantations planted to grow *T. melanosporum* (Turgeman et al., 2012; Molinier et al., 2013). Should it grow naturally on hazelnut plantations, and should legal regulations permit it, *T. aestivum* might provide farmers who grow hazelnuts with a considerable additional income. Consequently, the current study conducted a first systematic survey to assess the potential presence of *T. aestivum* on already existing hazelnut plantations in Germany using trained truffle dogs.

## Material and Methods

Hazelnut farmers were identified who might be interested in a truffle search on their plantations via an email request that was circulated among the members of the *Erzeugerorganisation Deutscher Haselnussanbauer* (Production Organization of German Hazelnut Growers), an organization of which most hazelnut farmers in Germany are members. Because a field soil pH > 7 is a necessary prerequisite for Burgundy truffle growth (Chevalier and Frochot, 1997), only plantations that matched this criterion were considered. In total, 14 farmers who owned plantations with a soil pH of 7–8 were interested in participating in the study. Their plantations were established between 10 and 13 years ago (2003–2006). The stand characteristics and the planting density of the hazel trees in these plantations were quite heterogeneous. Some planted shallow and rocky soil, others grew on rich soil with substantial water holding capacity. On such plantations, the crowns of the hazel trees often formed a closed crown resembling a small forest and ground vegetation was largely absent. However, the trees on plantations with a shallow soil were smaller and their crowns not closed, so that the space between them was covered with the typical vegetation of meadows and grassland. Frequently, stand density and tree size varied considerably even in one field. Some plantations were located directly next to forests or groups of trees, whilst others were surrounded by agricultural fields. Most of the plantations were located in the region between Würzburg and Munich, with the northernmost plantation being located at 49°53'14.3"N and 10°03'19.8"E and the southernmost plantation at 48°12'49.7"N and 10°58'50.4"E. One field was situated close to Donaueschingen in Baden-Württemberg at 47°58'41.0"N and 8°27'35.3"E. These plantations were visited between 29 September 2016, and 13 November 2016, using experienced truffle dogs that could find different kinds of hypogeous fungi, not only specimens of the genus *Tuber*. The fruit bodies found were identified via macroscopic and microscopic features following Montecchi and Sarasini (2000) and the key developed by Gold (2015). Depending on the field size and the motivation of the dogs to search for truffles, 30–60 min were spent in each plantation. The statistical analysis of the species distribution was performed using the R software package (R Core Team, 2017). The count data of the different species were fitted using a generalized linear model with Poisson-distributed errors. Analysis of variance was tested to check for possible significant differences between the species distribution.

## Results and Discussion

The dogs found eight different species of hypogeous fungi that grew naturally in the 14 hazelnut plantations. Some of them are shown in Fig. 1 However, *T. aestivum* was not among them (Table 1). Most frequently, *T. rufum* was found (10 plantations), followed by *T.*

*foetidum* (8 plantations). There was a significant difference between the species distribution ( $p = 0.04$ ). Both *Tuber* species were found significantly more often than the remaining six species, indicated by a weak value of  $p = 0.08$  for *T. foetidum* and a strong value of  $p = 0.04$  for *T. rufum*. However, all species found were considered relatively common (Montecchi and Sarasini, 2000; Höfert et al., 2016). In addition, several species of epigeous fungi grew on the plantations—sometimes, in such amounts that it was difficult to avoid stepping on them while walking. Most abundant were the fruiting bodies of the genus *Hebeloma*, but also *Laccaria laccata* grew in masses. Yet, none of the fungi species found on the plantations had possible commercial potential. However, it cannot be excluded that *Tuber aestivum* will sooner or later start colonizing the roots of the hazel trees, replacing existing mycorrhiza partners, as has happened elsewhere (Turgeman et al., 2012; Molinier et al., 2013). Yet, given that not a single ascocarp of this truffle species was identified, and given that the roots of the hazel trees seemed substantially colonized by other hypogeous and epigeous fungi species, the chances for this to happen might be low. It would be interesting to repeat the current survey in about 10 yr. Interestingly, four ascocarps of *T. aestivum* were found under a hazel tree that was specifically inoculated with this species when it was planted among other hazel trees cultivated for nut production. This demonstrated that the soil characteristics were principally suited for its development, and it also showed that inoculated hazelnut seedlings can indeed produce the desired truffles after several years of growth. Still, there were seven inoculated hazel trees in this field (planted in 2002) and only one seemed to produce truffles. The distance of this inoculated truffle tree to the next hazelnut trees for nut production was about 10 m—a distance that could easily be covered by the root systems of these trees and the mycelia, or by animal truffle consumers that distribute truffle spores. Thus, it is recommended to follow the development of this plantation's fungal community. Still, hazelnut farmers should not be too optimistic that *T. aestivum* will enter their plantations via a natural colonization process in the first 10–15 yr after the establishment of their plantations, even if the soil conditions appear suitable. Thus, the possibility to generate a reasonable additional income from typical hazelnut plantations in Southern Germany by harvesting naturally grown truffles appear low, even if the legal regulations would allow it.

## Conflict of Interest

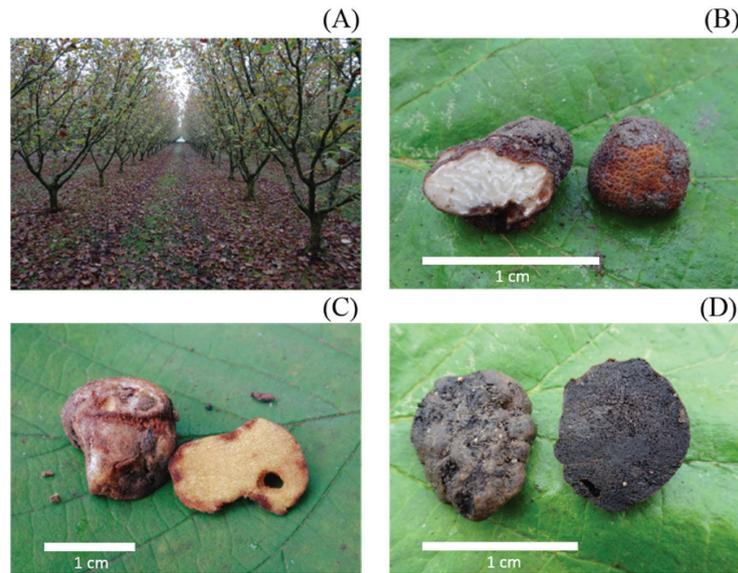
The authors declare that they have no conflict of interest.

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**Table 1** Hypogeous fungal species and numbers found in 14 hazelnut plantations

Fungal species	Number of plantations
<i>Balsamia vulgaris</i>	2
<i>Hymenogaster bulliardii</i>	3
<i>Hymenogaster luteus</i>	4
<i>Hymenogaster niveus</i>	2
<i>Hymenogaster cf. griseus</i>	2
<i>Melanogaster broomeanus</i>	2
<i>Tuber foetidum</i>	8
<i>Tuber rufum</i>	10



**Fig. 1** (A) Typical hazelnut plantation in Southern Germany. Hypogeous fungi growing in such plantations: (B) *Balsamia vulgaris*; (C) *Hymenogaster luteus*; (D) *Hymenogaster cf. griseus*. The three fruit bodies shown measured 1–1.5 cm

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