TRUFFLES AND SOIL

Maria DINCĂ, L. C. DINCĂ

Forest Research and Management Institute, Brasov branch
13 Closca street, Brasov, Romania, e-mail: dinka.lucian@gmail.com

Abstract. *Truffles are micoritic mushrooms that grow on the fine roots of trees (beech, oak, hazel, hornbeam, linden etc.) They are the only mushrooms that grow below the earth's surface. In order to harvest them, specially trained dogs are used. Furthermore, due to the fact that their fruit-body is formed in the first 10-20 cm of the soil, the soil characteristics are extremely important for determining truffle areas. This article presents the main characteristics of soils where the black truffle (Tuber aestivum), white truffle (Tuber magnatum) and black Perigord truffle (Tuber melanosporum) appear.*

Key words: *truffles, Tuber aestivum, Tuber magnatum, Tuber melanosporum, soil, pH, $CaCo_3$.*

INTRODUCTION

Truffles are mycoritic mushrooms. Mycorrhiza is a symbiosis between the roots of superior plants and the spawn of mushrooms or, in other words, the established cohabitation of certain mushroom categories and the roots of certain superior plants. In this case, the superior mycorrhized plat ensures the necessary amount of proteins, vitamins, stimulating growing and fructification elements for the mushroom. Due to this symbiotic relation, the mycorrhized plants grow better and the mushrooms fructify more abundantly

In Romania, the most spread truffle species is the black truffle - *Tuber aestivum/uncinatum* (fig 1), whereas the white truffle - *Tuber magnatum* is mainly found on small areas from the south part of the country. The main harvesting periods are: the summer black truffle (*Tuber aestivum*) from June 15 to January 30; the winter truffle (*Tuber brumale*) starting from the 1st of November up to 30 January; the white truffle (*Tuber magnatum*) from July 15 to December 15.

Fig.1. *Tuber aestivum* harvested in Bacau and Giurgiu districts (photo Dincă L.)

The main truffle host-trees are: different oak species (*Quercus* spp.), hornbeam (*Carpinus betulus*), beech (*Fagus sylvatica*), black pine (*Pinus nigra*), different linden

species(*Tilia* spp.), hazel (*Corylus avellana*), spruce (*Picea abies*), poplar (*Populus* spp.) or willow (*Salix* spp.).

Truffle harvesting can be achieved through numerous methods, some empirical such as: barefoot, by observing soil cracks, hitting the soil and analyzing the obtained sound (fig.2), using the olfactory sense or "the electronic nose", by observing the flight of certain insects and the list goes on, but also through more exact and ecologically correct methods: by using pigs (the main disadvantage being the fact that they immediately eat the truffles) and especially with the help of specially trained dogs).

Fig 2. Harvesting truffles (by hitting the soil in Maroc, or with the help of dogs in Romania) - photos Dincă L.

Some species of truffles, including *Tuber aestivum*, have high culinary value because of their scent. The scent is essential for attracting animals that spread the spores (Trappe and Castellano 1991).

Due to the fact that the truffles grow in the first 10-20 cm of the soil, the soil plays an extremely important role in spreading and developing this special type of mushrooms. Many researchers (especially those from France and Italy) have studied the characteristics of soils where truffle appear without reaching however an agreement regarding the necessary qualities for their presence. In our country, this is mainly a new field of study as the harvesting of truffles has only begun after the year 1995 and has reached a development and interest in the late 3-5 years.

MATERIAL AND METHODS

The specialty literature was firstly studied and certain determinations were accomplished in some areas of the country where truffles were identified. The physical and chemical properties of soils where truffle appear were mainly analyzed.

The soils requirements for realizing truffle plantations are more known as a 20 year tradition and experience already exists for this kind of cultures (almost the entire production of *Tuber melanosporum*, the second most valuable truffle after *Tuber magnatum*, is produced on this kind of plantations).

RESULTS AND DISCUSSIONS

The soils that are favorable for the black truffle -***Tuber aestivum*** were studied in many countries. As such, in Poland, HILSZCZANSKA D. et al., 2008, have observed that all *T.*

aestivum fruiting bodies detected were present in the land with higher water pH (7.15–7.53) and low phosphorus concentrations (0.30–0.59 g×kg^{-1}). C/N ratios of soils were above ten, indicating a preference of for soils that are poor in the readily degradable nitrogen. Similar results were found by WEDEN et al.(2004b) who compared the biotopes of *T. aestivum* on Gotland. The results are also in accordance with the findings of CHEVALIER AND FROCHOT (1997). For the agricultural land, a C/N ratio below ten is known to be an indication that the soil has been N fertilized (ERICKSSON et al. 1997). It seems that *T. aestivum* prefers soils poor in readily degradable nitrogen, and only one of the soil samples (Table 1) had a C/N ratio close to ten. High nitrogen content in soils can limit the development of mycorrhizae (RUDAWSKA et al. 2001). A higher Ca/Mg ratio could be favorable for *T. aestivum* fruiting. The K/Mg ratio was below two at all sites, which indicates that the plant uptake of magnesium was not negatively affected. However, WEDEN et al. (2004b) found *T. aestivum* on soils with K/Mg ratio well over two.

Table 1

Soil composition at the five *T. aestivum* sites in Poland (all soils represent Rendzic type of soil), Hilszczanska D. et al., 2008

Soil characteristics	B-T1	M-T2	M-T3	S-T4	S-T5
pH_{H2O}	7.53	7.33	7.08	7.27	7.15
pH_{KCl}	6.99	6.82	6.63	6.88	6.82
$CaCO_3$ (total)g×kg^{-1}	5.9	12.6	3.0	21.2	47.7
P (g×kg^{-1})	0.30	0.54	0.50	0.56	0.59
Ca (g×kg^{-1})	8.07	14.70	10.40	17.85	28.22
Mg (g×kg^{-1})	3.17	4.82	3.90	3.94	4.39
K (g×kg^{-1})	3.85	6.32	5.81	5.53	6.43
Ca/Mg	2.5	3.0	2.7	4.5	6.4
K/Mg	1.2	1.3	1.5	1.4	1.5
Carbon (organic) %	3.4	6.0	5.8	5.6	5.5
Carbon (total) %	3.5	6.2	5.9	5.9	6.1
Nitrogen (total) %	0.34	0.50	0.49	0.45	0.38
C/N	10.3	12.5	12.3	11.4	16.1

Soils from Italy that are favorable for *T.aestivum* have the following characteristics (Table 2):

Table 2

The main physical-chemical properties of soils specific to *T. aestivum* in Italy, Raglione, M. and Owczarek, M., 2005

Soil characteristics	Mean	Dev. std.	Min.	Max.	CV (%)
Clay (%)	33	13.7	2	78	41.5
Dust (%)	42	12.1	7	78	28.8
Sand (%)	24	10.4	12	65	43.3
pH_{KCl}	7	0.5	4.9	7.4	7.1
pH_{H2O}	7.8	0.4	6.3	8.5	5.1
$CaCO_3$ (total) (%)	35.7	23.4	0	75	65.5
C (%)	3.4	3.6	0.3	23.2	105.9
Fe (mg kg^{-1})	253.9	191.7	41.5	677.3	75.5
Mn (mg kg^{-1})	267	495.7	72.9	2183.8	185.7
Zn (mg kg^{-1})	12.1	6.1	4.8	22.2	50.4
Cu (mg kg^{-1})	61.1	41.2	7	163	67.4

By comparing the favorable soil conditions for *T. aestivum* from Sweden with the ones from France, WEDEN C., 2004, has observed that the French and Swedish truffle

populations both occupy lands with high pH (7-8) soils and low phosphorus concentrations (0.002-0.080%). The texture of the soil samples from the Swedish *T. aestivum* sites was silty to sandy, while French soils were more clayey. The truffle species can be found in both countries, in soils with K/Mg ratio well over 2 and C/N ratio about 12.

According to BRAGATO G. et al, 2006, the soils from Italy where *Tuber magnatum* is developed must have a high degree of humidity, are generally situated on bedrocks with a pH (in water) between 7.8 and 8.4 and with an average presence of active limestone (4%). For an area from Italy that is characteristic for the presence of this truffle, the same author has noticed that the truffle production areas (the alluvial soil alongside rivers) were characterized by soils with a very open sub angular blocky structure with a large amount of transmission and continuous elongated pores.The characteristics of these soils are rendered in Table 3.

Table 3

The main physical-chemical characteristics of soils specific to *T. magnatum* in Crete Senesi, Italy, Lulli L. et al., 1991

Soil characteristics	Area 1	Area 2	Area 3
Coarse sand 2000-250 μ (%)	4.8	2.0	4.9
Delicate sand 250-125 μ (%)	18.8	3.9	13.4
Very delicate sand 125-50 μ (%)	31.9	14.8	25.4
Coarse dust 50-20 μ (%)	15.9	23.9	16.7
Delicate dust20-2 μ (%)	17.3	33.8	24.0
Clay<2 μ (%)	11.3	21.7	15.5
pH_{H2O}	8.1	8.0	8.2
$CaCO_3$ (total) (%)	14.8	18.3	14.3
Active limestone(%)	2.87	6.18	5.35
Organic C(%)	0.89	1.28	0.80
Bulk density (g/cm^3)	1.3	1.3	1.4

In Croatia, BRAGATO G. et al. (2004), proved the need of *T.magnatum* for an alkaline, moist very well drained and aerated soil environment. Moreover, soils suitable for *T. magnatum* should be neither too dry nor too moist. In Motovun Forest, the decrease in production has been taking place in conjunction with public works that have modified the hydraulic equilibrium of the area causing an overall drying of the forest soil.

Fig 3. Soil profiles from Crete Senesi, Italy, area characterized by the presence of white truffle (photo:Lulli L.).

For *Tuber melanosporum*, GARCIA MONTERO et al., 2006, have analyzed the soils that are situated on steep inclines with considerable surface stoniness and moderately abundant fine sand and clay, which produce a texture that tends to be sandy clay loam soil. Most have a moderately basic pH and a low percentage of total carbonate, but an elevated concentration of active carbonate. The levels of organic carbonare moderate and the C/N ratio is close to 10, which indicates good humidification. They have high exchangeable cation complex values and 100% saturated exchangeable cations, with a high proportion of exchangeable Ca^{2+}, Mg^{2+} of abundant but relatively heterogeneous exchange, K^{+} in large and relatively homogeneous concentrations, and scarce and variable Na^{+}. They are well-structured, with a granular tendency and abundant pores,characteristics that are closely related to texture and levels oforganic carbon and calcium carbonate.

The simple statistical correlations and multiple regression analysis show that *T. melanosporum* burn size is related to the percentage of active carbonate present in the soil surface horizons, and they have quantified this relationship as:‘‘active carbonate explains 51% of the variance in burn size’’. Active carbonate is a finely divided fraction of calcareous rock which measures less than 50 mm, susceptible to rapid mobilization and very chemically active. Continuous formation of active carbonate maintains high Ca^{2+} levels in the soil solution and the exchangeable cation complex, as it counterbalances losses from leaching and other processes. RICARD(2003) indicated that it is difficult to judge the impact of active carbonate on truffle development because several factors must be considered. However, this author suggests that the lack of studies on active carbonate in *T. melanosporum* production is an oversight. GARCIA-MONTERO (2000) and Garcia-Montero et al. (2006) found that active carbonate and exchangeable Ca^{2+} account for up to 40% of *T. melanosporum* carpophore production. The presence of active carbonate and exchangeable Ca^{2+} is very important to *T. melanosporum* for various reasons, including the capacity to regulate soil pH and its participation inthe

flocculation of the colloidal fraction (clays and humus),which contributes to the organization and maintenance of the soil structure. Both these factors also play a part in the truffle's nutrition.

According to RAGLIONE, M. AND OWCZAREK, M. (2005) the soils from Italy that are favorable for *T. melanosporum* are well aerated, saturated in limestone, with an average pH in water of 7.9 (Table 4).

Table 4

Main physical-chemical characteristics of soils specific to *T. melanosporum* in Italy, Raglione, M. and Owczarek, M., 2005

Soil property	Mean	Dev. std.	Min.	Max.	CV (%)
Clay (%)	20.1	12.5	1.2	46.2	62.2
Dust (%)	51.4	16.6	4.9	83.3	32.4
Sand (%)	28.4	12.1	10.7	62.3	42.6
pH_{KCl}	7.3	0.1	7.1	7.7	1.8
pH_{H2O}	7.9	0.2	7.5	8.4	2.4
$CaCO_3$ (total) (%)	34.9	22.0	1.0	76.0	63.0
C (%)	3.2	1.9	0.6	9.8	59.2
Fe (mg kg^{-1})	148.5	90.3	31.7	323.3	60.8
Mn (mg kg^{-1})	237.7	132.5	53.3	534.1	55.7
Zn (mg kg^{-1})	9.0	7.7	1.1	38.7	84.7
Cu (mg kg^{-1})	17.9	17.8	1.1	88.9	99.4

CONCLUSIONS

From the point of view of pedologic conditions, *Tuber aestivum* is the most spread truffle. In comparison with other truffles that require the presence of an alkaline soil, the black truffle can appear also on weakly acid soils, with a pH between 6.6 and 7.3, as was also observed in Romania (Dinca L.).The species has a wide soil texture tolerance and the differences in the sites simply reflected regional geology. The soil must be well aerated and must have a constant humidity. This kind of truffle is present on the entire surface of our country, under beech stands, quercus and broad-leaved mixtures.

Tuber magnatum requires soils that are well supplied with water all year long, that have a significant presence of limestone, with subangular blocky structure and a large amount of transmission and continuous elongated pores. The active limestone from the soil must be over 1%. The species is present in the south area of the country (under the 45 parallel), especially under oak and mixture stands, in areas that lack an excessive summer drought.

Tuber melanosporum is not present in our country due to the fact that it doesn't resist at low winter temperatures. However, it seems that the mycelium of this truffle is present in our country's soil and after some extremely mild winters it can also appear in our country. This truffle also needs sufficient humidity, calcic soil skeleton and alkaline soils with the C/N report over 10 and with the presence of active carbonate and exchangeable Ca^{2+}.

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