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Short communication

Specific humus systems from mushrooms culture

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A B S T R A C T

The Veneto region, (north-east Italy), is the largest mushrooms production area in the Country. The mushrooms cultivation has become a real productive activity since the 50 s and in the last years has undergone several evolution processes, by the introduction of advanced technologies. Nowadays the Veneto region produces about 50% of the national mushrooms.

The spent mushroom substrate (SMS), obtained at the end of crop cycle, is legally considered a waste product. High quantities of SMC are available every year in the Italian mushrooms production industry and this waste poses a great environmental challenge in terms of management and sustainability.

The present work investigates the potential of SMS as organic fertilizer in vegetable production, by means of appropriate laboratory analysis of the chemical characteristics of three different types of SMS collected in the Veneto Region. Selected composts were composed by three different mixtures: poultry manure + horse manure (PH), straw + poultry manure (SP), straw + poultry manure + horse manure (SPH) in different proportions. Dry matter, organic matter, total N, P, and K, C/N ratio, pH, EC, anions and cations were measured.

The effects of different nitrogen sources on lettuce and leek production were evaluated. The requested nitrogen mineral fertilizer for each crop was partially or completely replaced by spent mushroom substrate (SMS). The 4 treatments were: unfertilized control (T0), mineral control (TMIN, 100% mineral fertilizer), T50 (50% SMS and 50% mineral fertilizer), T100 (100% SMS).

The cultivation with SMS as soil amendment and fertilizer generally provided positive effects for lettuce and leek performances showing yields comparable to mineral fertilization. Short cycle crops are favored by mixed fertilization because organic substrate usually requires a long time for mineralization. Organic fertilization is more effective for long cycle crops. Furthermore using SMS for a long time could help to increase soil organic matter and allow for recycling by-product from mushroom cultivation. The SMS utilization did not present problems for human health and heavy metal accumulation.

1. Introduction

The mushrooms cultivation process, especially in recent decades, is experiencing major changes both at management and production level.

The mushrooms cultivation is a very recent business activity and in few decades has greatly evolved.

The first notices about fungi date back to at 400 B.C. by Hippocrates who mentioned their medicinal properties (Beyer, 2003). The mushrooms cultivation started in the 17th century in France, where some farmers noted that fungi grew near horse manure heaps after they waste washing water used for rinse wild *Agaricus*. They did not know the basic biological process which is the bases of mushrooms cultivation and they limited their activity to collect spontaneously grew mushrooms. Few years later, near Paris, farmers started to storage the horse manure into quarries and they noted that mushrooms grew in the same way, even if the environment was completely dark (Maffi, 2011).

During the 18th century, *Agaricus bisporus* cultivation developed into the quarries near Paris even if the production was very low and discontinuos and was reserved for wealthy social class. Only in 1780, a French gardener obtained a year-round commercial production. Towards the end of 1800, after the American Civil War, he introduced mushroom growing in North America (Beyer, 2003).

This event was a milestone for mushrooms cultivation and, after this, farmers started to make their first attempts on grow substrate composting.

The 20th century saw the emergence of new and modern techniques which led to the mushroom cultivation used nowadays. A controlled fermentation process was introduced in order to convert carbohydrates in a nutrient complex that can be easily assimilated by *Agaricus;* the same process supports presence of specific bacteria promoting the conversion of ammonia in protein. Moreover, this process decomposes

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[1] https://www.youtube.com/watch?v=Eo9qB-vqSiQ.

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the straw, allowing it to absorb more water. In Italy, only 20% of companies produce their own the growing media, whereas most companies buy the growing media from specialized companies (Maffi, 2011).

At the beginning mushrooms were cultivated on a horse manure layer. Nowadays the pool of the matrixes is basically composed by horse manure, poultry manure, straw and gypsum. Currently the mushrooms cultivation is a standardized process. Companies are highly specialized making use of grow chambers completely automatized equipped with temperature, humidity and any other environmental parameter control in order to obtain a great yield and quality. Concerning growing media, it is very stable from a chemical point of view. Obviously the initial composition can vary depending both on the organic matrices used and on the percentage of each single raw material used (Fidanza et al., 2010). When the composting process is complete, the substrate is placed into mushrooms growing chambers on beds or trays and used as a substrate for mushrooms growing. At the end of growing cycle the "spent" substrate is removed from the growing chambers and steam pasteurized to kill insects, pathogens and leftover mushroom (Beyer, 2003). The output material is an organic matrix enriched with nutrients, especially nitrogen, which may play a relevant agronomic role when used as a fertilizer or soil improver (Jordan et al., 2008; Roy et al., 2015). Growing mushrooms is a kind of "waste recycling activity", that reuses a waste coming out from agriculture and then producing a waste that can be re-used in agriculture (Fig. 1).

According to international literature, are required 5 kg of growing substrate to obtain 1 kg of *Agaricus bisporus* (Williams et al., 2001; Rasib et al., 2015) and the SMS is an unavoidable by-product of mushrooms cultivation (*Agaricus bisporus*). The Italian mushrooms production is particularly effective and distinguished by the remarkable skills of producers that achieves production volumes significantly higher than those of the US and the Netherlands. In particular, the Italian production doubled the US and is three times higher than the Netherlands one in the period 2010–2013 (FAOSTAT). The result if this high production volumes, is a remarkable production of SMS. It is estimated that the SMS volume is near 300,000 t/year (Maffi, 2011).

Several studies were conducted attempting to recycle the spent mushroom substrate in different ways and not only in agriculture.

Some authors found bioremediation properties of SMS when used in contaminated water, soil or air and substrate contaminated with pesticides. For example, in order to purify air contaminated by hydrogen sulfide (H_2S) Shojaosadati and Elyasi (1999) used a biofilter formed by sludge from the leather industry mixed with spent mushroom substrate and with grounded snail shell. More than 99% of H_2S was removed from H_2S loaded air.

Moreover, there are some studies about vegetable production, both in the greenhouse (Gonani et al., 2011) and in open field, fruit crops (Delver and Wertheim, 1988; Uzun, 2004) and nursery crops (Medina et al., 2009; Zhang et al., 2012). The spent mushroom substrate found application also in pest management for different species (Yohalem et al., 1996; Stoner et al., 1996) and another alternative use of SMS was described by Lin et al. (2014) biogas production.

In our experiments we tested the SMS as fertilizer in open fields horticulture crop rotation. Particularly lettuce and leek, were considered to evaluate the SMS effect compared with mineral fertilization.

2. Materials and methods

The experiment was conducted during the 2014 and the first month of 2015 at the Experimental Station "L.Toniolo" University of Padova, northeast of Italy (45° 21′N, 11° 58′E). Fourteen companies located in the Veneto region were sampled, and 3 different types of substrate were considered:

- SP = straw + poultry manure;
- HP = horse manure + poultry manure;
- SPH = straw + poultry manure + horse manure.

Before using SMS as fertilizer we need to know the amount of macro-nutrients that are present inside. For this reason, SMS was analyzed and its characteristics recorded: this preliminary work was carried out in our laboratories. Specifically, the dry matter content was analyzed according to the official method EN 13040; the organic matter content was obtained according to the official method EN 13039. As regards the nitrogen content, was used to the Kjeldahl method. The pH determination was performed according to the official method EN 13037 and the electrical conductivity was determined according to the official method EN 13038. Anions and cations content (method EN 13652) was quantified by ion chromatography. In addition to the above analysis, the amount of certain heavy metals was obtained by placing

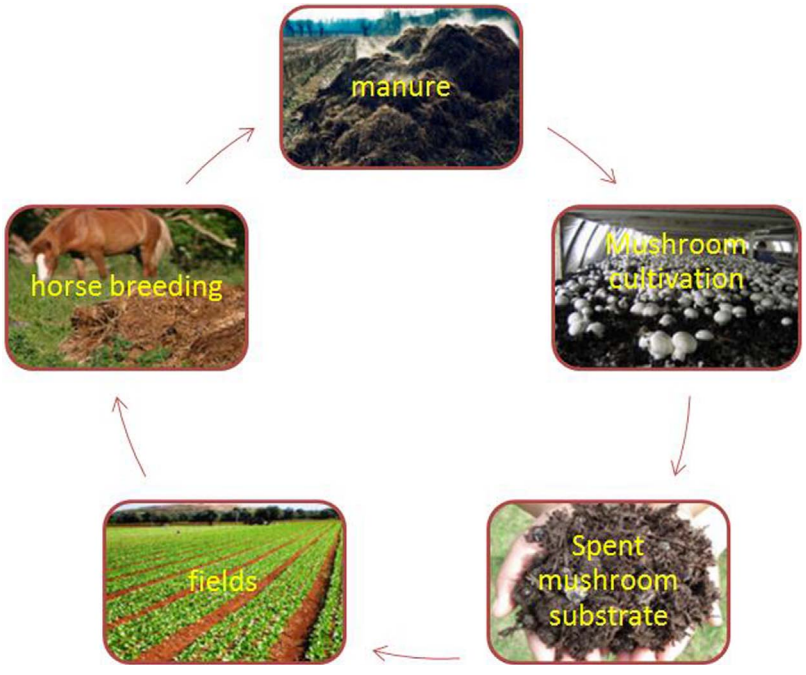

Fig. 1. The cycle diagram that summarizes the link between agriculture and mushroom cultivation.