Journal of Fruit and Ornamental Plant Research vol. 12, 2004 Special ed.

USE OF SPENT MUSHROOM COMPOST IN SUSTAINABLE FRUIT PRODUCTION

Ibrahim Uzun

Akdeniz University, Faculty of Agriculture, Department of Horticulture
07070, Antalya, TURKEY
e-mail: uzun@akdeniz.edu.tr

(Received May 6, 2004/Accepted October 1, 2004)

A B S T R A C T

Mushroom compost is produced from chopped straw, poultry manure, gypsum and water. After the mushrooms have been harvested, the spent compost can be used in organic farming to improve soil water infiltration, water holding capacity, permeability and aeration. Spent mushroom compost contains a lot of salt and unstable organic material, so it should be aged for about two years before applying. This allows for leaching of organic solutes and decomposition of organic matter. Spent mushroom compost contains about 1-2% nitrogen, 0.2% phosphorus and 1.3% potassium. After being aged for 18 months, phosphorus and nitrogen do not change, but potassium can decrease. The characteristics of spent mushroom compost are described, and the possible advantages and disadvantages of using SMC in fruit growing are discussed.

Key words: mushroom compost, fruit production

INTRODUCTION

By 2003, world mushroom production had reached three million tons (Anonymous, 2003). About 40% is produced in China, followed by the USA (12%), the Netherlands (8.8%), France (6.3%), Poland (3.5%), the United Kingdom (3%), Italy (2.8%), Canada (2.5%), Spain (2.5%), and Ireland (2.2%). If about five kilograms of fresh compost are needed to produce one kilogram of mushrooms, then about 15 tons of spent mushroom compost (SMC) are produced each year (Tab. 1). Although many mushroom species are cultivated around the world, seventy percent of world production is derived from only three mushroom: the white button mushroom *Agaricus*

bisporus (32%), the shitake mushroom *Lentinus elodes* (25%), and the oyster mushroom *Pleurotus* spp. (14%).

Table 1. Mushroom production and estimated spent compost production around the world (2003)

Country	Mushroom production [t]*	Estimated spent mushroom compost [t]**
China	1,309,497	6,547,485
USA	391,000	1,955,000
Holland	280,000	1,400,000
France	200,000	1,000,000
Poland	110,000	550,000
UK	95,000	475,000
Italy	90,000	450,000
Canada	81,000	405,000
Spain	80,000	400,000
Ireland	70,000	350,000
Others	457,437	2,287,185
Total	**3,163,934**	**15,819,670**

* FAO Production yearbook (2003)

**Mushroom production multıplied by 5

COMPOSTING AND MUSHROOM CULTIVATION

The most commonly cultured mushroom is *Agaricus bisporus*, also known as the white button mushroom. It is grown on compost consisting of straw, horse manure, poultry manure, gypsum, nitrogen-containing compounds, and water. There are many recipes for this compost, which must provide an adequate supply of all nutrients for mushroom growth since mushrooms do not have chlorophyll and cannot produce carbohydrates by photosynthesis.

Compost is produced by first moistening straw with water for a few days. Then, manure, gypsum and nitrogen supplements are added. The compost is stacked in heaps two meters wide and two meters high, either in the open or under a roof. Stacks are turned with an automatic turning machine every three days. The internal temperature of the stacks should not exceed 70°C during the composting process, which lasts for about three weeks. Compost is transferred to a controlled temperature room, where it is pasteurized for 6-8 hours at 60ºC, conditioned 5-7 days at 48-52ºC, and cooled down to 25ºC. This eliminates most microbes that could compete with the mushrooms for food and hamper mushroom growth. It also converts toxic ammonium into protein, which the mushroom can assimilate.

The finished compost is filled into bags, trays or shelves. Bags are inexpensive and disposable. Spawn is added to the compost, and the bags are placed in growing rooms. After two weeks, the compost is completely colonized by mycelium, and can be covered with a casing material, usually peat. Three weeks after casing, the first mushrooms can be harvested. Mushrooms appear in week-long cycles called flushes. Most mushrooms are harvested during the first three flushes, after which productivity declines. The used compost is usually called spent mushroom compost (SMC), although the terms spent mushroom substrate and champost are sometimes encountered. SMC should be pasteurized at 70ºC for twelve hours to prevent the spread of pests and diseases (Griensven, 1988).

CHARACTERISTICS OF SPENT MUSHROOM COMPOST

The physical, chemical and biological properties of SMC vary greatly depending on composting processes, cultivation techniques and weather conditions. SMC does not contain any pests or weed seeds, because of the high temperatures associated with the composting and pasteurization processes. SMC also contains very low levels of pesticides and heavy metals, well below the limits set by the US Environmental Protection Agency. SMC has a bulk density of between 300 and 600 g/L, and a carbon/nitrogen ratio between 8 and 27. (Anonymous, 2004c; Anonymous, 1996a).

Nutrient content

Fresh SMC contains about 1-2% nitrogen, 0.2-0.3% phosphorus, and 1.3-2.4% potassium (Tab. 2).

About 94% of the total nitrogen is in organic form (Anonymous, 2004a; Steward et al., 1998). After the SMC is applied, soil microorganisms convert the organic nitrogen to ammonium and nitrate, which can be assimilated by plants. Mineralization is affected by soil moisture, organic matter, carbon/nitrogen ratio, and temperature, and is most rapid under warm and moist conditions. The nitrogen in SMC is mineralized at an average annual rate of 15%. After about five years, about 30% of the total nitrogen in the SMC is mineralized, based on the release rate of 15% at the first year, 8% the second, 4% the third, 2% the fourth and 1% the fifth year. The rate of inorganic nitrogen leaching from SMC is considerably slower than from chicken litter applied at the same rate (Sullivan, 1998; Travis et al., 2003).

Fresh SMC should not be used for fertilizing and soil amendment because it contains a lot of salt. It should be weathered for at least six months. During weathering, very little nitrogen and phosphorus is lost, but potassium decreases considerably due to leaching. Potassium is much more soluble than nitrogen and phosphorus (Anonymous, 2004a). In biowaste composts, 10-

15% of the nitrogen, 30-40% of the phosphorus and 65-85% of the potassium are released in available forms during the first year (Biala, 2000). In laboratory experiments in which SMC was leached with distilled water, 15% of total nitrogen, 33% of total phosphorus and 94% of total potassium were leached after sixty days. (Guo et al., 2001a)

Table 2. Detailed Analysis of Spent Mushroom Compost (after Anonymous, 2004a)

Content	Units	Fresh SMC	Weathered 8-16 months SMC	Horse manure	Chicken Manure
Sodium	% dry weight	0.72	0.22	0.3	0.13
Potassium	% dry weight	2.35	1.03	1.2	2.25
Magnesium	% dry weight	0.71	0.91	0.25	1.2
Calcium	% dry weight	4.93	6.16	0.85	8
Aluminum	% dry weight	0.40	0.80	0.06	0.2
Iron	% dry weight	0.11	0.92	0.06	0.25
Phosphorous	% dry weight	0.36	0.55	0.9	2.5
Ammonium nitrogen	% dry weight	0.11	0.03	NT	NT
Organic nitrogen	% dry weight	1.83	1.89	3.5	6.11
Total nitrogen	% dry weight	1.93	1.92	3.5	6.11
Solids	% dry weight	43.39	49.43	24	20
Volatile solids	% dry weight	62.78	44.29	NT	NT
Manganese	ppm dry weight	332.92	438.62	115	300
Copper	ppm dry weight	46.26	61.68	25	20
Zinc	ppm dry weight	103.32	136.41	130	175
Lead	ppm dry weight	14.89	18.17	NT	NT
Chromium	ppm dry weight	8.33	11.31	NT	NT
Mercury	ppm dry weight	0.07	0.19	NT	NT
Nickel	ppm dry weight	11.93	15.74	24	20
Cadmium	ppm dry weight	0.45	0.65	0.1	0.4
pH		7.23	8.05	7.2	6.5
N:P:K ratio		1.9:0.4:2.4	1.9:0.6:1.0	1.2:0.3:0.4	3.0:1.3:1.2

SMC contains a lot of organic matter. SMC contains 40% dry matter and 60% water (Tab. 3). Half of the dry matter is ash (inorganic matter), and the rest is organic. About 50% of the original organic matter present at the start of the composting process is consumed during the composting process. Another 20% is consumed during mushroom growth. Losses in compost weight and amount of dry matter from the beginning of composting to end of cultivation are shown in Table 3 (Griensven, 1988). Magnesium deficiency can result when SMC is applied at high rates due to antagonism with potassium.

If SMC is weathered under field conditions, the major cations in leachate are K^+, Na^+, Ca^{2+} and Mg^{2+}, and the major anions are Cl^-, SO_4^{2-} and NO_3^{2-}. SMC should be stacked no higher than 90 cm to prevent excessive amounts of nitrate in the leachate under the pile (Guo et al., 2001b).

Table 3. Changes in compost during various phases of composting and growing (after Griensven, 1988)

Stage	Compost [kg]	Dry Matter [kg]	Water [l]	Moisture [%]
Starting material	1 600	400	1.200	75
End of composting (filling)	1 000	280	720	72
End of conditioning (spawning)	712	235	477	67
Casing	625	225	400	64
End of cropping	458	182	276	60

Salt content

The electrical conductivity is usually higher in SMC than in soils, and is generally over 4 dS/m. For example, in the UK, the conductivity of SMC fell from an original level of 5.5 to 2.0 after nine moths of weathering (Noble, 2002).

Most plants are sensitive to high levels of salt in the soil. Salt-sensitive plants, such as stone and pome fruits, require that the conductivity be below 4 dS/m (Tab. 4). Salt tolerance can be increased by using salt resistant rootstocks, which take up less chloride. For example, Marianna rootstock is salt resistant and increases the salt tolerance of plum and prune cultivars grafted on it.

Table 4. Salt tolerance of fruit crops (after İşcan et al., 2001)

Tolerance	Conductivity [ds. m^{-1}]	Examples
Sensitive	2-4	apple, pear, plum, prune, apricot, peach, strawberry
Somewhat tolerant	4-10	grape, fig, pomegranate, olive
Tolerant	> 10	date palm

Problems due to high salt levels can result when too much SMC is applied to the soil, or when plants are grown directly in SMC. Conductivity gradually goes down due to leaching during the weathering process, depending on rainfall. Leaching peaks during the fifth and sixth months of weathering, and stabilizes after twelve months. Most of the salts originally present in the SMC are released during the first year of weathering.

APPLICATION OF SPENT MUSHROOM COMPOST

Time of application

SMC can be applied to soils from autumn to early spring. In cold climates, SMC should be applied in autumn before the soil freezes. SMC should not be

applied in the summer because this stimulates late season growth, which can be damaged by autumn frosts. SMC should not be applied to young plants because they are particularly sensitive to high levels of salts and ammonium.

Rate of application

It is difficult to give exact amounts for SMC application because the nutrient content varies from case to case. SMC should be analyzed for nutrient content and applied at a rate determined by local soil conditions and the choice of the cultivar to be grown. Nitrogen, phosphorus and potassium uptake by mature fruit trees is shown in Table 5.

Table 5. NPK uptake by mature fruit trees [kg ha^{-1} $year^{-1}$] (after Zabunoğlu and Karaçal, 1986)

Crop	**N**	**P**	**K**
Pome fruits	70	9	60
Stone fruits	85	9	65
Grapes	110	15	110
Oranges	170	23	120

SMC is usually applied in broadcast or in bands. Broadcast application provides a uniform effect throughout the orchard. Application in bands permits the use of lower doses of SMC. After application, SMC should be incorporated into the soil in order to prevent nitrogen loss.

Good agricultural practice dictates that no more than 250 kg/ha of nitrogen should be applied to soils when there are no problems with water quality, and no more than 170 kg/ha to soils when water quality problems exist. When applied at a rate of 10 tons/ha, SMC supplies approximately 80 kg/ha of nitrogen. Excessive nitrate leaching leads to soil acidification and potential groundwater pollution (Carton and Magette, 1998; Travis et al., 2003).

Storage of Spent Mushroom Compost

According to environment protection regulations in Pennsylvania (USA), SMC may be stacked up to 90 cm high in fields with a seasonal ground water table 50 cm below the surface. In addition, SMC must be weathered in the open for two years to ensure adequate decomposition of organic matter and leaching of inorganic solutes (Guo et al., 2001b).

SMC storage areas must be located at least 30 meters away from any body of water or public road, 100 meters from any domestic well, and 300 meters from any public water source (Anonymous, 2004c). SMC should be stored as far away from the mushroom house as possible to minimize the transfer of pests and diseases.

USE OF SPENT MUSHROOM COMPOST IN ORCHARDS

Regulations in the USA and the EU permit the use of SMC in organic orchards unless it contains prohibited substances. In sustainable fruit production, SMC is used as a fertilizer or soil amendment, as a mulch, or as an alternative pesticide.

Fertilizer or soil amendment

SMC is not a good fertilizer because it does not contain a lot of nitrogen, phosphorus and potassium in comparison to mineral fertilizers. It is more expensive than mineral fertilizers in terms of the nutrient content per unit weight. However, when SMC is used as a fertilizer, nutrients are released slowly over a longer time, and plants can use them more effectively. SMC also improves soil structure by increasing organic matter, water capacity, microbial activity, and soil temperature, and by decreasing soil compaction. The benefits of SMC in orchards are modest in the first year, but increase considerably in subsequent years.

SMC is a good source of phosphorus and potassium, but not of nitrogen. When SMC was applied to wheat fields, SMC had to be applied together with other sources of nitrogen at least during the first year (Duggan et al., 1998). The application rate depends on the nutrient content of the SMC, the nutrient requirements of the crop to be grown, and the local soil conditions, field topography and climate (Anonymous, 1996a).

Mulch

When SMC is used as mulch, it is usually applied in a 5 cm thick layer. Because this may not provide adequate weed control, a 10 cm should be applied (Tsaoir and Mansfield, 2000). Mulching with SMC provides reasonable weed control, but reduces yield in apple orchards, probably because it contains toxic levels of plant nutrients (Tab. 6).

Table 6. Yield of apples after different mulch, herbicide and fertilizer applications (after Tsaoir and Mansfield, 2000)

	-- Mulch + Herbicide	-- Mulch + Herbicide	+ Fertilizer + Mulch	+ Mulch + Fertilizer
Yield [kg plot^{-1}]	1517 a	1261 c	1281 bc	1328 b

Alternative pesticide

Compost tea is a liquid extract of SMC prepared by mixing one part of compost with four parts of water. It contains soluble nutrients and beneficial microorganisms, including bacteria, fungi, protozoa and nematodes (Szmidt et al., 2001).

Compost tea can be used to control apple scab disease (*Venturia inaequalis).* Compost tea reduces conidia germination in *V. inaequalis* by 98%, probably due to heat stable compounds produced by anaerobic microorganisms during the incubation of the compost slurry (Anonymous, 2004b; Anonymous, 1996b).

The composition of compost tea varies depending on the type and maturity of the compost, and on the extraction process. For this reason, there are conflicting reports on the efficacy of using compost tea to control diseases.

CONCLUSION

SMC is more expensive than mineral fertilizers in terms of the nutrient content per unit weight, but provides many benefits that mineral fertilizers cannot. SMC improves the biological, physical and chemical characteristics of the soil. For this reason, SMC should be applied once every few years in sustainable fruit growing.

REFERENCES

Anonymous 1996a. Using compost. Composting factsheet. British colombia ministry of agric. And food, factsheet nr 362500-15.

Anonymous 1996b. Compost extracts and the biological control of foliar plant disease. www.pprc.org/pprc/rpd/fedfund/usda

Anonymous 2003. FAO production yearbook. http://faostat.fao.org

Anonymous 2004a. Environmental Guidelines for mushroom producers. www.agf.gov.bc.ca/resmgmt/fppa/environ/mushroom/mush_d.htm

Anonymous 2004b. Sustainable methods for the control of apple scab. www.newnets.com.au/oaa/applescab.htm

Anonymous 2004c. www.tipperarynorth.ie/rawdata/environ

Biala J. 2000. The use of recycled organics compost in viticulture. Proc. 6th Int. Congress on Organic Viticulture. www.elspl.com.au

Carton O.T., Magette W.L. 1998. The implications of Irish legislation and regulations for the land spreading of manures from intensive agricultural enterprises. www.ramiran.net

Duggan J.T. Mccabe, Hennerty M.J., Maher M.J 1998. Can spent mushroom compost be used as a crop nutrient source. www.ucd.ie/agri/html/homepage/research_96_98/

Guo M.J., Chorover J, Rosario R., Fox R.H. 2001a. Leachate chemistry of field-weathered spent mushroom compost. J. ENVIRON. QUAL. 30:1699-1709.

Guo M.J., Chorover J., Fox R.H. 2001b. Effects of spent mushroom substrate weathering on the chemistry of underlying soils. J. ENVIRON. QUAL., 30: 2127-2134.

Griensven L.J.L.D. 1988. The cultivation of mushrooms, 515 p.

Işcan S., Tepeli Ö., Uyan A., Yaşar M., Çavdar A. 2001. Sulamanın temel esasları. ADANA ZIRAI ÜRETIM IŞLETMESI VE MEKANIZSYON EGT. MERK. YAYIN NO: 2

Noble R. 2002. RECOVEG. www.hri.ac.uk/recoveg

Riker D. 2002. Handling and using of the spent mushroom substrate around the world. www.Mushworld.com

Stewart D.P.C., Cameron K.C., Cornforth I.S. 1998. Inorganic-N release from spent mushroom compost under laboratory and field conditions. SOIL BIOLOGY AND BIOCHEMISTRY 30/13: 1689-1699.

Sullivan D. 1998. Fertilizing with biosolids. Oregon State Univ. Pnw 508.

Szmidt R.A.K., Dickson A.W. 2001. Use of compost in agriculture. Scottish Agric. College.

Travis J.W., Halbrendt N., Hed B., Rytter J., Bates T., Butler S., Levengood J., Roth P. 2003. A practical guide to the application of compost in vineyards. www.fpath.cas.psu.edu

Tsaoir S.M., Mansfield J. 2000. The potential for spent mushroom compost as a mulch for weed control in bramley orchards. Proc. Conf. Integrated fruit production. ACTA HORT. :427-429.

Zabunoğlu S., Karaçal I. 1986. Gübreler ve gübreleme. AÜ. ZIR. FAK. YAYINLARI: 993.

UŻYCIE KOMPOSTU PIECZARKOWEGO W ZRÓWNOWAŻONEJ PRODUKCJI OWOCÓW

Ibrahim Uzun

STRESZCZENIE

Kompost pieczarkowy składa się z pociętej słomy, pomiotu ptasiego, gipsu oraz wody. Może on być wykorzystywany w produkcji organicznej w celu polepszenia właściwości wodno-powietrznych gleby. Kompost o optymalnych właściwościach otrzymuje się w ciągu dwóch lat kompostowania, podczas którego związki organiczne rozkładane są na związki proste. Kompost ten zawiera około 1-2% azotu, 0,2% fosforu oraz 1,3% potasu. Zawartość potasu w kompoście pieczarkowym w dużej mierze zależy od długości kompostowania. Właściwości kompostu pieczarkowego są opisane w pracy. Możliwość jego zastosowania w produkcji owoców jest dyskutowana.

Słowa kluczowe: kompost pieczarkowy, produkcja owoców