Evaluation of Orykta ™ as a Source of Micronutrients to Improve Yield and Quality of *Agaricus bisporus* Mushrooms

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Abstract: Recent research conducted at Penn State has demonstrated that cultivated mushroom yields can be increased significantly by addition of a commercial micronutrient fertilizer to the compost at spawning. These studies also revealed that about 70% of the yield increase was due solely to the manganese present. However, other micronutrients present were involved in about 30% of this improved yield. Orykta™ is a micronutrient-rich fertilizer product mined in Nevada and marketed by PMMR Corporation that has compositional similarities and price advantages compared to other commercially available micronutrient fertilizers. Hence, the objective of this research was to add Orykta™, with and without additional manganese, to compost at spawning, and determine effects on yield and quality of *Agaricus bisporus* mushrooms. Orykta ™ added alone at 1.25 and 2.5 (% dry wt. of compost) and manganese added alone at 200 ppm were found to have no significant effect on crop yield. However, addition of Orykta ™ at both levels with 200 ppm of manganese increased yields in the first flush by about 9%. There were no significant effects of any added micronutrients on yield in the later flushes or size, whiteness, color, or solids content of the mushrooms. These results indicate that Orykta ™ amended with manganese may be useful to improve mushrooms yields and thus warrants further study.

Key words: *Agaricus bisporus*, micronutrients, manganese, increased mushroom yields, Orykta ™

1 Introduction

Recent research conducted at Penn State has demonstrated that cultivated mushroom (*Agaricus bisporus*) yields can be increased significantly by addition of a commercial micronutrient mixture to the compost at spawning. [1] These studies also revealed that about 70% of the yield increase was due solely to the manganese present in the micronutrient mixture. However, other micronutrients present were involved in about 30% of this improved yield. Orykta™ is a micronutrient-rich product mined in Nevada and marketed by PMMR Corporation that has compositional similarities and price advantages compared to other commercially available micronutrient mixtures. Hence, the objective of this research was to add Orykta™, with and without additional manganese, to compost at spawning and determine effects on yield and quality of *Agaricus bisporus* mushrooms.

2 Materials and Methods

2.1 Composting and growing

The compost used for this experiment was a blend of switch grass straw and wheat straw-bedded horse manure prepared using an aerated-bunker Phase I and tunnel Phase II process at the Mushroom Test Demonstration Facility (MTDF) on the Penn State University campus. The crop was grown at the Mushroom Research Center (MRC) in plastic tubs (56.5×44.5× 24.2 cm) filled with 22.7 kg of compost at spawning. Chemical analysis of the compost is presented in Table 1. The spawn (Sylvan 140) was pre-treated with thiophanate-methyl (Topsin M 70WP) fungicide at a rate of 0.9 g/kg (a.i.) of spawn and added to the compost at 150 g/tub. The fungicide

was first added to gypsum (50 g/kg of spawn). Supplement (Promycel Gold, Amycel) was also added at spawning at 272 g/tub and micronutrients were mixed with the supplement as follows:

Control (no addition)
Orykta™ - 1.25% (85 g Orykta™/tub)
Orykta™ - 2.5% (170 g Orykta™/tub)
Manganese (Mn) - 200 ppm (4 g $MnSO_4.H_2O$/tub)
Orykta™ - 1.25% + 200 ppm Mn
Orykta™ - 2.5% + 200 ppm Mn

Table 1. Chemical analysis of compost

Analyte	Results (as is basis)	Results (Dry weight basis)
pH	7.7	--
Soluble Salts (1:5 w:w)	9.72 mmhos/cm	--
Solids	32.2%	--
Moisture	67.8%	--
Organic Matter	20.7%	64.4%
Total Nitrogen	0.6%	1.8%
Carbon	11.3%	35.1%
Carbon:Nitrogen Ratio	19.8%	19.8%
Ammonium N	4.0 mg/kg	12.3 mg/kg

The experiment involved six replicate tubs per treatment. After thorough mixing of spawn and supplement into the compost, the tubs were placed in the growing room in a completely randomized design. Spawn growth was conducted for 14 days at 22°C and then tubs were cased with a mixture of sphagnum peat moss and limestone at about 80 percent moisture.
Samples of compost were removed from each tub before casing and transferred to one-gallon Ziploc® storage bags. Compost samples were then dried in a drying oven at 60°C for 24 hr, divided into three sub-samples and then immediately stored in sterile sample bags and then analyzed for mineral content at the Agricultural Analytical Services Laboratory on campus (see Table 2).
The mushrooms from both crops were harvested over three flushes. On the peak production day of each flush, mushrooms from each treatment were randomly selected from the entire growing room. Only mushrooms free of scales and disease and those with tight caps were picked for analysis of initial color, solids content and mineral analysis.

2.2 Yield, color and solids analysis

As the mushrooms were harvested they were separated by treatment, weighed and counted. These weights were recorded to determine the cumulative yield of each flush, and overall three flushes, for each treatment. Yields were expressed as the weight of the mushrooms harvested (kg) per unit area of bed space (m^2). To determine an approximate value for the size of the mushrooms, the total weight of mushrooms picked from each tray was divided by the total number picked from each tray for each flush.
Immediately upon arrival at the laboratory, three replicates consisting of eight mushrooms from each treatment were randomly selected and placed into eight-ounce linear polystyrene tills (Tray-Pak Corp., Reading, PA). These mushrooms were then evaluated for initial whiteness (L-value) using a hand-held Chromameter (Model CR-200, Minolta Corp, Ramsey, NJ). Three readings were taken on the cap of each mushroom. The mean of each replication was averaged to calculate initial whiteness (L-value) for each treatment.

Table 2. Mineral content of compost at casing following treatment with micronutrients

Treatment	P	K	Ca	Mg	Mn	Fe	Cu	B	Al	Zn	Na
	%, d. w.				µg/g, d. w.						
Control	0.53	2.19	2.21	0.51	252	2199	37	22	1230	125	2090
Orykta-1.25%	0.51	2.22	2.15	0.50	241	2401	34	22	1481	120	2143
Orykta-2.50%	0.50	2.14	2.00	0.50	286	2933	37	21	1558	121	2125
Mn-200ppm	0.50	2.19	2.00	0.47	504	2995	35	21	963	123	2128
Orykta™-1.25% + 200 ppm Mn	0.53	2.20	2.29	0.52	496	2762	39	22	1171	130	2166
Orykta™-2.50% + 200 ppm Mn	0.48	2.10	2.05	0.48	777	3382	35	21	2403	114	2204

The chromameter was calibrated before each use by employing a standard white calibration plate that was included with the instrument. The L*a*b color coordinate system was used for all color measurements. In this system, L-value indicates whiteness and a* and b* values are chromaticity coordinates. L-values range from 0-100, and increasing L-value indicates a higher degree of whiteness.[2] The standard white tile used for calibration of the chromameter has values of L = 97.00, a* = -2.00, and b* = 0.00.[3, 4]
After the initial color readings were taken, twenty-four mushrooms from each treatment were quartered by hand using a standard kitchen knife. From each mushroom three quarters were discarded and one quarter was retained. Four randomly selected quarters, each from a separate mushroom, were placed in an aluminum weigh dish and weighed. This resulted in six replications for each treatment. After weighing, the samples were placed in a walk-in freezer and stored for twenty-four hours at 0°C. After 24 hrs of frozen storage, the samples were freeze-dried (VirTis model Genesis 25XL, VirTis Inc., Gardiner, NY) to a constant weight. Upon completion of the freeze-drying process, the samples were removed from the freeze dryer and immediately weighed. The difference between the fresh weight and the dry weight was used to calculate the solids content of the mushrooms. After recording the dry weight, the individual samples were transferred to sterile sample bags (Fisher Scientific, Pittsburgh, PA), and stored in glass desiccators until needed for further analysis.

2.3 Mineral analysis: mushrooms

The mushroom quarters used for total solids determination were powdered using a mortar and pestle. They were then sent to the Agricultural Analytical Services Laboratory on the University Park Campus of the Pennsylvania State University for mineral analysis. Inductively-coupled plasma atomic emission spectroscopy provided data for the following eleven elements: P, K, Ca, Mg, Mn, Fe, Cu, B, Al, Zn and Na (Table 3).

2.4 Mineral analysis: compost

Immediately after spawning, a quantity of compost was removed from each bag or tray and transferred to a one-gallon zip lock freezer bag. The compost samples were then placed in a walk-in freezer and stored for twenty-four hours at 0°C. After twenty-four hours of frozen storage, the compost samples were removed from the zip lock bags, placed onto trays, and freeze dried to a constant weight. Compost samples were then sent to the Agricultural Analytical Services Laboratory for mineral analysis as described above.

2.5 Statistical analysis

All statistical analysis was performed using Statistical Analysis System software, version 8.2 (SAS Institute Inc., Cary, NC). The experiment was completely randomized with the sources of variation consisting of tray (replication) and treatment. ANOVA and Fisher's mean separation procedure was used to determine significant

differences between treatments for yield, initial quality data, point of sale quality data, solids content and mineral content for compost and mushrooms.

3 Results and Discussion

Orykta™ added alone at 1.25 and 2.5 (% dry wt. of compost) and manganese added alone at 200 ppm, were found to have no significant effect on crop yield (Table 3). However, addition of Orykta™ at both levels with 200 ppm of manganese increased yields in the first flush by about 9%. There were no significant effects of any added micronutrients on yield in the later flushes or size, whiteness, color, or solids content of the mushrooms (data not shown).

The influence of micronutrients added to the compost on the mineral content of the mushrooms is presented in Table 4. There was no apparent difference in mineral composition of the mushrooms from the different treatments indicating that the mushrooms did not incorporate any of the additional micronutrients added to the compost.

Table 3. Yields of mushrooms from composts treated with micronutrients

Treatment	Flush			
	1	2	3	Total
Control	15.8 AB	9.4 A	2.0 A	27.2 A
Orykta-1.25%	15.9 AB	8.9 A	2.0 A	26.8 A
Orykta-2.50%	15.4 B	9.1 A	1.5 A	26.0 A
Mn-200ppm	16.5 AB	9.1 A	2.0 A	27.6 A
Orykta™-1.25%+200 ppm Mn	17.2 A	8.4 A	1.9 A	27.5 A
Orykta™-2.50% + 200 ppm Mn	17.3 A	8.1 A	2.4 A	27.8 A

Data are means of six replications. Means followed by the same letter are not significantly different (a = 0.05)

4 Conclusions

Previous research at Penn State[5] demonstrated that the level of certain micronutrients in mushroom compost may not be adequate to support maximum crop yield. Results of this study indicate that Orykta™ amended with manganese may provide needed micronutrients and thus be useful to improve mushrooms yields. Also, it appears that further studies with Orykta™ and manganese are warranted.

Table 4. Mineral content of second flush mushrooms harvested from compost treated with micronutrients

Treatment	P	K	Mg	Ca	Mn	Fe	Cu	B	Al	Zn	Na
	%, d.w.			μg/g, d.w.							
Control	1.14	4.09	0.11	254	5	21	28	12	1	49	517
Orykta-1.25%	1.21	4.26	0.12	149	5	20	30	10	1	50	501
Orykta-2.50%	1.21	4.35	0.12	217	5	22	29	10	1	49	497
Mn-200ppm	1.15	4.23	0.12	278	5	20	26	13	1	47	517
Orykta™-1.25%+200 ppm Mn	1.15	4.24	0.12	211	5	21	26	14	1	45	526
Orykta™-2.50% + 200 ppm Mn	1.12	4.27	0.12	236	5	20	26	9	2	44	534

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