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SOIL

Indigenous Microorganisms, Compost or Commercial Inoculants?

Matt Bedeaux • December 14, 2022 0 9 minutes read

A permanent agriculture requires knowledgeable support of soil ecosystems. Many farmers are starting to use "biofertilizer" products to enhance soil, essentially prepared mixtures of beneficial organisms. The market for these products is expected to be worth $1.94 billion by 2027 (Fortune Business Insights, 2020). But there are still significant challenges with commercial inoculants, mainly because their success depends on unique site conditions and competition with existing organisms (Bellows et al. 2020). What if we could instead make biological inoculants composed of local (i.e. "indigenous") organisms using local materials, within a month?

That is exactly the goal of indigenous microorganism (IMO) inoculants, a recipe of Korean Natural Farming. In 2022, Northeast SARE (Sustainable Agriculture Research and Education, Northeast United States) provided a research grant to Unadilla Community Farm to examine some basic properties of IMO and compare them to other common soil amendment methods. This research project had three questions:

1. What happens to the chemical nutrient content and microbiological community throughout the stages of IMO production?

1. How do chemical nutrients and microbiology of top-dressing ready IMO compare to compost, and the commercial mycorrhizal fungi inoculant MycoGrow® Soluble (Fungi Perfecti, LLC)?

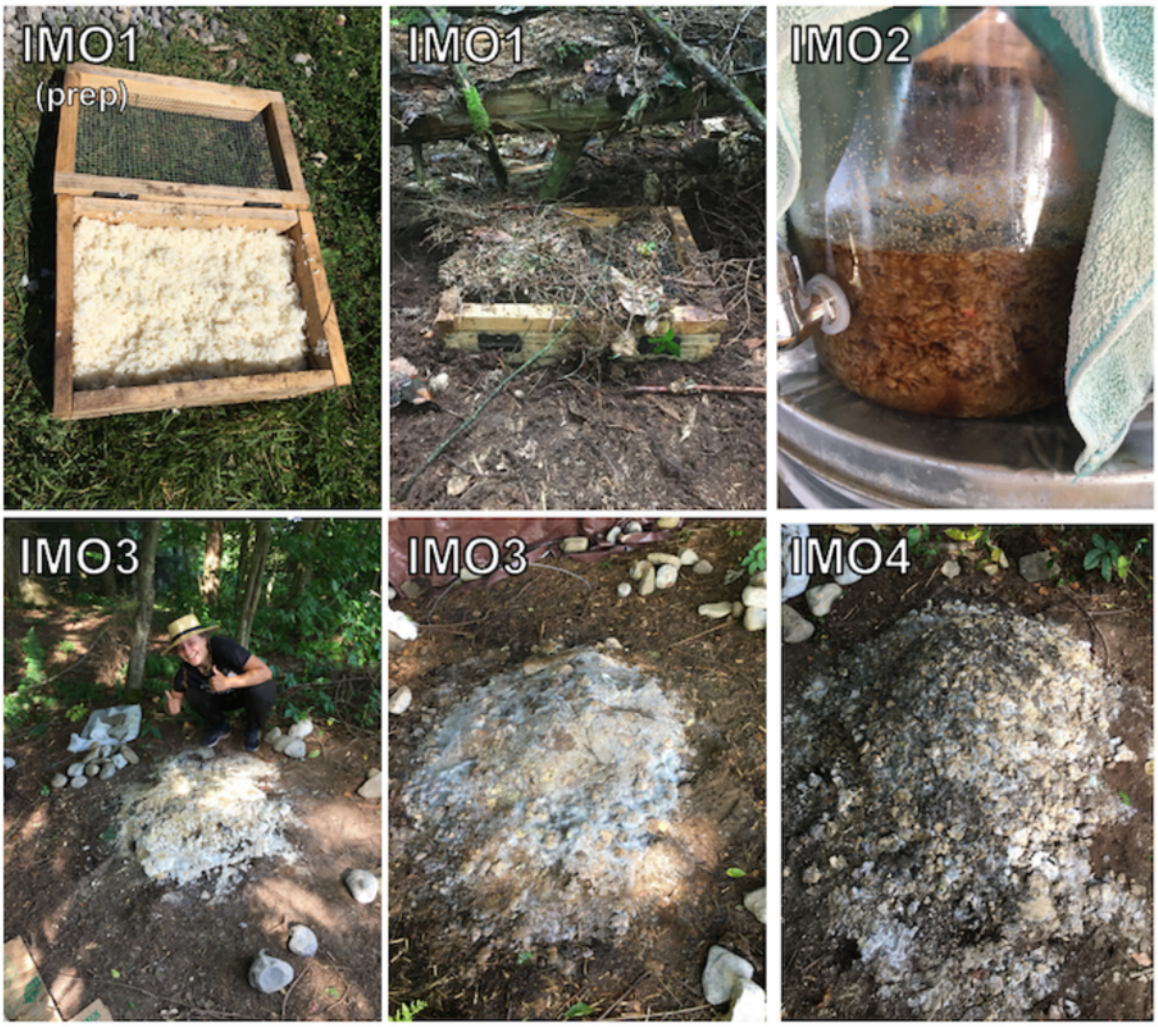
1. How does the cost and labour of each of these methods compare to their nutrients and biology?

Another minor objective of this study was to compare wheat bran-derived IMO to rice bran-derived IMO, since wheat bran is more accessible in the Northeast US than rice bran, which is traditionally used. If you're curious about the details, the full report for this project is available here.

Making IMO

The IMO recipe occurs in four stages. IMO1 is made by placing a wooden box filled with cooked white rice in the wilderness for several days. Once the rice is completely covered with white mould, it is combined with an equivalent volume of brown sugar and allowed to incubate in a jar for two days. This mixture, which is called IMO2, enters the IMO3 stage by being diluted with water, mineral-enhanced salt, and fermented plant juice (FPJ), which has its own recipe. The mixture is used to inoculate bran which is allowed to sit for approximately 1 week or until the IMO3 is completely colonised with mould. The final phase of IMO production (IMO4) is made by mixing the mouldy bran with an equivalent amount of soil and allowing another two days. At this point the IMO4 could be applied as top dressing or via foliar spray (O'Hara 2017; Zuraihah et al. 2012). After several troubleshooting trials, two final batches

were made: one rice bran batch (RIMO4) and one wheat bran batch (WIMO4). These were sampled for analysis.



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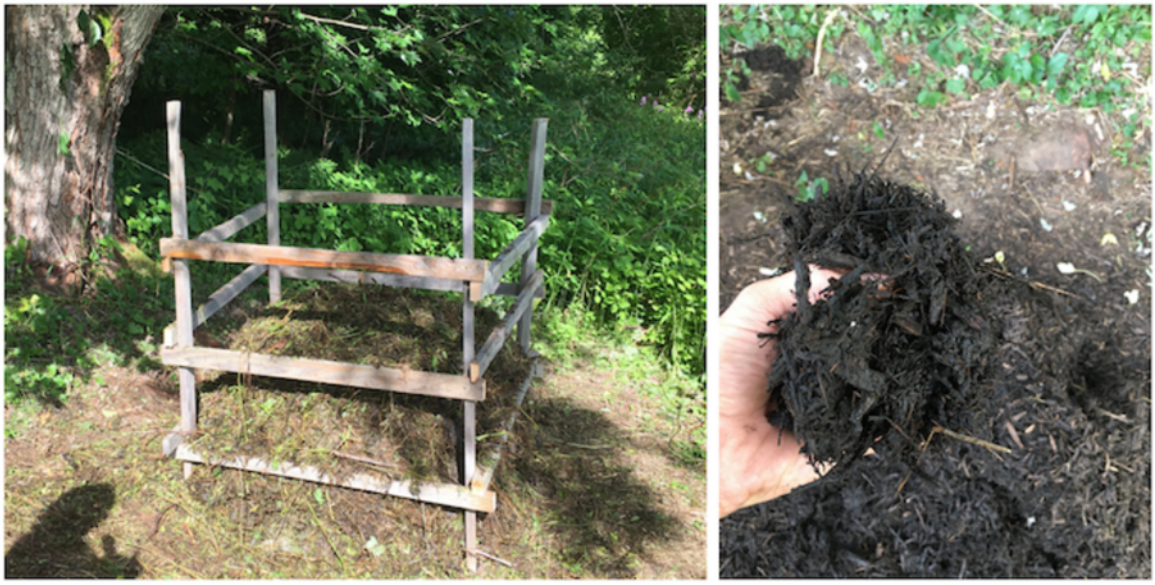
Making Compost ('Berkeley' Hot Composting Method)

It was desired to make compost in the same timeframe as IMO (2-3 weeks). Thus, the compost had to be very hot (55-65 °C), very moist (>50%), and turned very often (every other day after initial static 4 days). Using these parameters should yield topdressing-ready compost in 18 days (Eliades 2010). Due to a miscalculation with the carbon-to-nitrogen ratio, this study's compost consistently hovered in the mid 70's C, even despite additions of wood chips. The full decomposition took 24 days, at which point it was

sampled for analysis. Municipal compost was also sampled to compare a cooler, slower, less labor-intensive composting method.



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Altogether, samples collected included

- Soil from the forest site where IMO1 was collected
- IMO2 derived from the same batch of IMO1
- Rice bran-produced IMO4 (RIMO4) derived from the same IMO2
- Wheat bran-produced IMO4 (WIMO4) derived from the same IMO2
- Farm-produced "hot" compost
- Municipal compost
- MycoGrow® Soluble (Fungi Perfecti, LLC)

For the following tests:

- Chemical nutrient analysis at Penn State's Agricultural Analytical Services Lab.
- Microbiome assessment (aka total food web test) at Web of Life Regenerative Land Care.
- Fungal genus identification (most prominent) and bacterial species identification (top three most prominent) at EMSL Analytical, Inc.

And now... the results!

Nutrient analysis

Table 1 – Nutrient Analysis. Data provided by Penn State's Agricultural Analytical Services Laboratory.

	IMO1 Site (aka "Forest Soil")	IMO2	Rice bran IMO4 (RIMO4)	Wheat bran IMO4 (WIMO4)	Municipal Compost	Farm-produced Compost
pH	6.8	5.9	5.8	6.5	8.1	7.9
Est. soluble salts (ppm)*	<50	300	2650	3500	1450	3050
Organic matter (%)	12.3	99.9	13.5	9.8	41.5	78.7
Total nitrogen (%)	0.481	0.25	0.433	0.429	1.338	2.024
Organic nitrogen (%)	0.481	0.247	0.421	0.382	1.335	2.019
Carbon (%)	6.9	39	7.5	6.3	25	26.1
C:N Ratio	14.3	155	17.4	14.6	18.7	12.8
Phosphorus** (ppm)	1,200	260	4,100	2,600	1,600	3,000
Potassium** (ppm)	1,700	741	3,900	3,300	4,800	14,000

*converted from mmhos/cm using Scherer and Meehan 2019.

** given on an elemental basis (i.e., P and K, not P_2O_5 or K_2O).

Here are the most interesting takeaways in Table 1:

- Acidic pH in both IMO4 preparations is consistent with anaerobic qualities: putrid odour, high moisture content, and being covered in cardboard.
- Assuming IMO would be used at the same density as compost, both IMO4 preparations have lower organic matter and nitrogen relative to the two composts. Higher quality soil may be used instead of inorganic topsoil to increase IMO nitrogen and organic matter.
- Phosphorus and potassium in IMO are comparable to compost.
- Farm-produced compost has higher nutrient and salt levels than municipal compost, which is expected due to freshness.
- Nitrogen and organic matter amounts in the forest soil are similar to IMO4's. This poses questions about whether biological conditions will also be similar.

There are many reasons why comparing MycoGrow to the other methods is challenging. Firstly, MycoGrow is applied in a diluted form, so nutrient levels in Table 1 are misleading. Diluted nutrient amounts are provided in Table 3. Second, since MycoGrow is a biological inoculant, it is applied with a different goal than compost or IMO, which directly add living organisms and nutrients. Thirdly, using the recommended rate of application for mycorrhizal fungi inoculants may not result in the advertised benefits (Benami et al. 2020, Tarbel and Koske 2007). Farmers may have to experiment to find an effective application rate. While this study may provide some useful information about MycoGrow, our ability to compare it to other methods turned out to be limited.

To continue, Table 2 presents data on the microbiome assessments.

Microbiome assessments

Table 2 – Microbiome Assessments. Data and recommended ranges are provided by Web of Life Regenerative Land Care.

	Rec. soil range	Rec. compost range	Forest soil	IMO2	RIMO4	WIMO4	Mun. Compos
Fungal biomass (ug/g)	675 – 9000	101 – 1012	2,794 ± 1,362	0	78 ± 173	243 ± 509	18 ± 28
Bacterial biomass (ug/g)	135 – 900	135 – 1350	6,656 ± 1,564	2420 ± 548	17,137 ± 2,598	21,693 ± 4,342	9,720 ± 2,813
F: B ratio	5 – 100	0.6 – 0.9	0.42	0	0.0046	0.011	0.0019
Protozoa (#/g)	>10,000	>50,000	220,000 ± 200,000	0	0	0	65,216 : 145,827
Nematodes (#/g)	~600	~300	0	0	0	320	160
Oomycetes (ug/g)	0	0	0	772 ± 694	22,484 ± 3,967	2,235 ± 3,002	0

Large variability throughout Table 2 is due to the variable concentrations that these organisms appear under the microscope. In the case of standard deviations that exceed 70% of the average, the measurement is not discussed. Despite this caveat, there are still many interesting results:

- There is low or no fungi in IMO and municipal compost. This may be explained by the short culturing duration and/or lack of wood.
- All materials were bacterially dominant.
- IMO preparations contain few fungi, few bacterial predators (protozoa and nematodes), and potential pathogens (oomycetes).
- Forest soil conditions were not re-established in IMO4's.
- The farm compost contained the most prolific and balanced microbiome, whereas the municipal compost was lacking in fungi, protozoa, and nematodes.

Oomycetes, fungi-like eukaryotes to which many plant diseases are attributed (Fawke et al. 2015, Fry and Gruenwald 2010), were observed in IMO2, WIMO4, farm compost, and significantly in RIMO4. Fortunately for the farm compost, resilience against pathogens is conferred by diverse soil ecosystems. Interestingly, municipal compost, which is the only material to which water was not added, did not have oomycetes.

When MycoGrow was examined no organisms were observed, though spores were. Fungi Perfecti's claim of 1.2 billion propagules of ectomycorrhizal fungi per pound of MycoGrow was verified through observation of sufficiently numerous 6-13 um diameter spores. However, their claim of 92,000 endomycorrhizal propagules per pound, which would have larger diameter, could not be verified. In any case, since other materials had low or no fungi, inoculants such as MycoGrow might fill this gap.

Fungi and Bacteria Identification

In addition to the microbiome assessments, fungi and bacteria were specifically identified via swabs taken from the same sites. Studies show that culturing organisms in lab may not produce results that reflect wild conditions (Davis et al. 2005), but results do identify organisms that are present *at some level.* MycoGrow was not submitted for identification since mycorrhizae would not be identified using this method. Here are the main takeaways:

- Most fungi identified in the forest soil are not observed in the IMO4's.
- Presence of anaerobic-capable bacteria in the IMO4's confirms other anaerobic properties of IMO4 discussed above.
- While there were aerobic bacteria in the forest soil, there were none in IMO4.
- There were similar fungi and bacteria in both IMO4 preparations.
- Compost and IMO share some fungal genera, but no bacteria.
- Farm-produced compost demonstrated the highest fungal diversity.
- There are both aerobic and anaerobic bacteria in the farm-produced compost.

Costs, labour, and key properties of each method.

Table 3 shows the calculated costs, labour, and results converted from Tables 1 and 2 (nutrients and microbiomes) using the bulk density of each soil amendment. Costs will vary with location, brand, etc.. All properties are given per 100 square feet of 1 inch depth of topdressing. It is advised not to use these numbers as a basis for large scale projects (>400 square feet) since labor and cost scale nonlinearly. Keeping that in mind, here are some key takeaways:

- IMO costs more, but requires less labour than composting on-farm. Slower, less labour intensive methods of composting may be chosen.
- Nutrients in the municipal compost are comparable to farm compost. This is not what was found in Table 1 (nutrient analysis), but now we are comparing these materials by volume, not by mass.
- The cost of the 50 gallons of wood chips used in the farm-produced compost is higher than the total amount of municipal compost in 100 square feet at 1 inch depth. Cheaper sources of carbon-rich material would incentivize on-farm composting.

Table 3 – Cost, labour, and key properties of each amendment scaled to the same application area of 100 square feet at one inch depth.

	RIMO4	WIMO4	Municipal compost	Farm-produced compost	MycoGrow*
Cost ($/100 ft^2)	$122.12	$46.02	$4.94	$9.78	$3.63
Labor (hrs/100 ft^2)	5.5	5.5	0	41.5	0
Total mass (lb/100 ft^2)	169.7	163.0	97.2	65.8	0.025
Organic matter (lb/100 ft^2)	22.9	16.0	40.3	51.7	0.0129
Nitrogen (lb/100 ft^2)	0.7	0.7	1.3	1.3	0.000207
C:N ratio	17.4	14.6	18.7	12.8	37.2
Phosphorus (lb/100 ft^2)	0.7	0.4	0.2	0.2	0.0000142
Potassium (lb/100 ft^2)	0.7	0.5	0.5	1.0	0.00132
Fungal biomass (lb/100 ft^2)	>0	>0	>0	>0	0**
Bacterial biomass (lb/100 ft^2)	2.9 ± 0.4	3.5 ± 0.7	0.9 ± 0.3	0.3 ± 0.1	0
Oomycete biomass (lb/100 ft^2)	3.8 ± 0.7	>0	>0	>0	0
Protozoa count (#/100	0	0	0	3.87E7 ± 1.91E7	0

ft^2)					
Nematode count (#/100 ft^2)	0	5.22E4	1.55E4	1.34E5	0

*utilizes manufacturer's recommended application rate of 1lb/4000ft^2

**fungal growth upon inoculation is beyond the scope of this study

Conclusions

Despite connections drawn by other studies between the biology of IMO at different stages (Keli'ikuli 2018), this study showed distinct biology at each stage. Anaerobic conditions exist throughout the IMO production, which contributed to dominance of bacteria, negligible bacterial predation, as well as oomycetes. When compared to the other methods studied, IMO also had higher cost and lower nutrition. Farm-produced compost hosted the most nutrient dense, diverse soil ecosystem of all materials studied, which would provide biological benefits regardless of its low mass density. Composting would be even more cost effective if cheaper sources of carbon and less labor-intensive methods were used.

Although MycoGrow provides negligible nutrients and endomycorrhizal spores were not observed in this study, the use of MycoGrow *in combination* with IMO or compost may provide unique advantages since these other methods contained low or no fungal biomass. Nonetheless, finding an effective application rate would require experimentation by the farmer (Benami et al. 2020, Tarbel and Koske 2007) and the success of non-indigenous fungi depends on site conditions (Bellows et al. 2020). Readers interested in methods of producing "indigenous" mycorrhizal fungal inoculants on site are referred to Englander 2013.

Regarding IMO production, this study shows key areas for improvement. For example, lowering the requirement for >50% moisture may improve access to oxygen, and finding alternatives for sugar and topsoil would reduce the cost and perhaps improve nutrition. After all, it appears that using wheat bran

instead of rice bran did not affect the quality of the IMO very much. In any case, as we continue to investigate and develop cost-effective and locally appropriate ways to support soil life, I recommend composting in the meantime.

This material is based upon work supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, through the Northeast Sustainable Agriculture Research and Education program under subaward number FNE22-001. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

#IMO #Mycorrhizal fungi #Nematode #Oomycete #Protozoa #Soil