Significance of Stability-Maturity Testing and Plant Bioassays to Assess Composts for Inclusion in Soil Building Projects

Key words:

Compost respiration, oxygen deprivation,
volumetric respiration, ammonia volitization, plant bioassay.

INTRODUCTION

MANUFACTURED SOILS AND STABILITY

The preparation of artificial and built soils involves skills in sourcing ingredients which are compatible and suitably stable to foster and sustain healthy growing environments. In horticulture the traditional use of natural soil has been largely replaced with peatmoss often amended with heat expanded volcanic glass (perlite) and hydrated silicates (vermiculate). These products are all relatively stable biochemically and behave near-neutral to plants (nutrient additions are assumed). Though of biological origin, peatmoss, due to its slow formation over centuries, behaves in a stable fashion in short term growing environments.

COMPOSTS AS RECYCLED INCLUSION

Recently, composts have been promoted as a full or partial replacement both for soil and peat-based media. The principal driver to composting is driven by societal perception of the need to recycle organic matter instead of filling landfills. In contrast to traditional, horticultural media composts are relatively unstable since they result from the recent, planned decay of recycled organic matter (ROM). ROM may include, leaves, grass clippings, shredded wood, manures, and sludges, none of which taken alone are used appreciably in horticulture.

SIGNIFICANCE OF RESPIRATION OF OXYGEN TO CO_2

The natural exchange of oxygen for CO_2 during decay of residual organic matter is normally so low as to not result in measurable deprivation of pore space oxygen in soils. Plant roots require a substantial influx of available air since plant-rootlet aerobic respiration occurs at very high rates when soils are warm and plants are undergoing rapid expansion. The addition to soil of high rates of fresh organic matter can result in episodic oxygen deprivation with immediate, harmful effects on plants, often referred to as phytotoxicity. With proper soil management and tillage, the temporary negative effect from incorporation of crops residues and manures is normally very small. However, composts of uncertain stability are being promoted at increasing rates in soil mixes. Presently in the USA, there are only minimal national standards relating to compost production and maturity. There are no industry-independent guidelines which exist that pertain to compost use in horticulture and for manufactured soils. The premise of this review is that the horticultural and manufactured soil industries must expect to produce their own set of test criteria suitable for their particular applications and cannot rely on the compost industry and its promoters to be responsible to produce appropriate guidelines. Some information provided in this review on the origins of test methods for the compost industry cast significant doubt as to whether any of these compost tests are appropriate for soil building.

RATE OF RESPIRATION AND NITROGEN VOLATIZATION

Soils are the ultimate yardstick for plant growth. Under normal circumstances, soil respiration rates range from 10-100 ppm CO_2-C per day and do not interfere with plant growth. In contrast, even medium active composts will possess respiration rates of 5,000 - 40,000 ppm CO_2-C or 2 – 3 orders of magnitude greater than soils. Therefore, it must be logically expected that in constructing soils, a respiration threshold could be exceeded which would become harmful to plant growth in the short and longer term.

Additionally, composts exhibit a nitrogen stability factor which is outgassing of volatile ammonia. As a dissociated gas, NH_3 is hazardous to plants and animals, and may intoxicate plants at concentrations as little as 500 ppmv. Free ammonia does not normally exist in soils and if it does so temporarily from use of urea or anhydrous ammonia, it rapidly associates with water to form non-volatile ionic ammonium (NH_4) which is readily absorbed into the soils exchange system. Immediately following this, common soil bacteria transform it into nitrate ion, which plants readily absorb.

Composts are often nitrogen rate-limited and are typically managed with nitrogen components to obtain suitably low C:N ratios which enable active microbiological degradation. The result is that often the considerable amounts of free ammonia exist. The levels may easily attain 4,000- 20,000 ppmv in the interstitial pores of the compost. Since ionic ammonium will disassociate into free ammonia if the pH in compost is elevated, the pH range must be considered very carefully. A survey of leaf and yard waste composts showed pH values from 6 to 8.9 suggesting that even leaf and grass composts pose risks of free ammonia.

Examples of harmful effects from improperly sourced composts do exist but are mostly private. A Rhode Island nursery lost an entire planting of ericaceous shrubs to immature compost in 2001, investigated both by Univ. of Mass and Woods End Labs. In a landscaping project in the Big Dig, Boston, a construction company (Marino) sourced immature compost which when landscaped began to emit odors requiring the material to be removed at great cost. In Maine, while landscaping the new headquarters for a national bank near Camden, all the ornamental trees were lost due to use of immature compost in the soil mixes. A 2008 study by a British Horticultural Agency found many composts are which have passed state standards are unsuitable for horticultural mixes. A 2002 California study which examined plant growth related to maturity index tests, which include Solvita, showed excellent correlations.

NEED FOR TESTING

Composts must be properly tested for stability factors relevant to plant growth in high rate environments. Presently they are not, for the industry has developed simple and convenient voluntary standards, such as length of heating and relative stability, which allow production to go ahead with minimal concerns. It is generally believed that "market forces" will, if needed, impose the relevant, higher standards. Without proper testing of compost there is a likelihood of settling or subsidence issues caused by continued in-situ decay and plant damage resulting reduced oxygen or ammonia present in the root environment.

DISCUSSION: VOLUMETRIC TESTING FOR COMPOSTS

Testing composts volumetrically (volume-based) as opposed to gravimetrically (weight basis) provides an avenue which relates directly to horticulture and manufactured soils. During degradation compost loses organic manner causing an increase in relative ash. Additionally, compost material packs down over time from moving actions and pile height forces. The net result of these forces is that the bulk density of compost increases considerably over time, from as low as 12 lb/ft^3 to as high as 65-70 lb/ft^3. This is of great significance when evaluating stability. If the rate of respiration per unit of volume is not known, then a regular respiration test result may be not only meaningless, but appear acceptable when it is not. This respiration rate per unit volume defines ultimately the amount of air a plant root must compete for.

The compost industry uses a CO_2 rate stability guide for that is a gravimetric test (rate of CO2 unit per weighed mass). Not only this, but the units reported (mg CO2/g OM) bear no direct practical significance to growers and soil manufacturers. As a result of the increase in compost density over time, even if respiration rate stays the same (as reported in a gravimetric test) the oxygen deprivation potential per volume of soil mix may actually have climbed to unacceptable levels. Scientists who developed the Solvita test for respiration had this in mind since the procedure is standardized for same volume samples. The change in gaseous composition in the sample headspace accurately reflects the likely behavior in soil mixes at given bulk density. Results of trials over time show that composts which are declining in apparent CO2 respiration as per the USCC test, are actually increasing in volumetric respiration (and hence oxygen demand) due to how the two factors cross each other out. For large landscape jobs the respiration potential per as is volume of material is a critical factor to know. No other test can perform this.

Another volumetric test used for composts (mostly in Europe) is the Dewar self-heating test, listed as a standard in at least 4 countries. Similar to Solvita, this procedure exposes a volume of compost to a heat-capturing device to assess its potential to cause appreciable heating. The test has not been applied for horticultural evaluation, but studies at Woods End Labs reported in the textbook *Microbiology of Composting*, showed that rates of compost heating greater than 10C above ambient were associated with extremely deleterious plant effects when used at appreciable rates to formulate growing media. This was due to volumetric oxygen depletion. These effects correlated directly with volumetric respiration by Solvita test. The compost industry has been very slow to recognize the horticultural implications of the simple approach.

PLANT BASED BIOASSAYS AS COMPOST MATURITY TESTS

The concept of using a plant for testing compost is that in theory, if a plant is not harmed by compost, the compost should be ok. The problem with the concept is that there are many biotypes that survive in anoxic and harsh environments, and would be logically unsuitable indicators. AN OECD plant used in many aerobic toxicity studies is garden cress (*Lepidium sativa)* presently the most widely used bioassay plant for compost quality, introduced in Europe in 1988 and now a standard test for compost in many countries, including Switzerland and Germany, where composting rates statistically are the highest in the world. In Switzerland, the test was developed by plant scientists, and is required to be performed in open and closed containers. The significance of this is that the closed container traps gases (NH3, methane, ethylene) that may be emitted by unstable composts are known phytotoxins harmful to plants. If present in sufficient amounts they will build up in the test jar and manifest inhibitory action on seedlings. The test correlates highly with oxygen demand of composts, and is more suitable than most tests since the plant result in visible. Despite some attempts to introduce the cress test into America, the compost industry has not accepted it, but chosen the cucumber assay, first proposed by the US Composting Council in 1996. In attempting to trace the origins of the cucumber test used as a USCC required test for “maturity”, it was discovered that ti was pre tested in a massive Minnesota funded compost quality assay. The study, called MNCUP, was managed by Malcom Pirnie, and was completed in 1995-1996. The executive summary of the study states that the test methods examined were developed together with the Composting Council for its draft TMECC of methods for examining composts, funded by Procter & Gamble. While the USCC announced in 1996 that the cucumber assay has been tested and would be now used as the official USCC test, the MNCUP documents show a contrary result, and the consultants did not include it in the recommended methods. Scientists who have examined the data discovered that the cucumber assay performed extremely poorly and gave contradictory results when comparing different facilities (8 facilities were exhaustively tested over a period of one year). In some cases the cucumber reacted *positively* to increased oxygen demand, meaning compost of increasing immaturity, while in most cases, it was inconclusive with very poor regression results to any tested compost traits. It is therefore inexplicable why this test was selected by the USCC unless purposefully to choose a plant that would be a non-indicator of quality. This would be typical of self-interest for an industry promoting its product.

Later testing has confirmed these contradictory results for cucumber. A *Composting News* (2005) article reported studies by Woods End Labs showing conflicting results when cress is tested against cucumber. Close examination of the findings showed cucumber preferred less stable compost if associated with increased nutrients especially when significant ammonium was present. This contradicts common sense with compost maturity. A closer examination of variability showed that the physical constraints of the test set up as specified in TMECC create non-random plant variability due to edge effects of the plantlets that throw out typically large true-leaves, inducing shade impairment of neighbor plants. It was concluded that without further work, the plant test will be inconclusive for compost quality. A 2004 Ohio State University trail reported in the journal Soil Biology Biochemistry showed similarly contradictory results of using cucumber when evaluating differing composts of known maturity. The compost industry has made no effort to take stock of these scientific results and continues to promote the same unrefined methods.

SUMMARY

Composts vary widely in quality with potentially severe effects on plant growth. The compost industry has adopted broad, lenient standards that serve the general purpose to ascertain that a material is reasonably compost. Uses of compost in specialized applications, however, where use rates are potentially (and intentionally) high, such as container horticulture and built soils, requires that standards suitable for this application be more carefully chosen. Test methods not designed for this purpose should be rejected, but such a rejection does not constitute rejection of compost or disapproval of the process that industry has employed in constructing minimum standards. The message to the US Composting Council, is to acknowledge that the TMECC and STA methods reflect a minimum-approval approach for compost that does not sufficiently protect the interests of using composts in the manufactured landscape.

In contrast, scientists working in horticulture and compost quality have described sufficiently methods that may be very appropriate to these applications. These include the Dewar Self Heating test, presently the most widely used compost procedure in the world, and the Solvita test, used in virtually all countries that make compost. Additionally, the cress bioassay is widely tested and validated and excellent for horticultural purposes.

OTHER IMPORTANT TESTS

Maturity, stability and plant bioassays are not alone sufficient testing for composts. Important accessory tests include C:N ratio, pH, bulk density, salinity and ammonium:nitrate ratio. The first 4 are common in compost laboratories, while many soil laboratories are able to offer the ratio test. Perhaps the best approach would be to review the California Maturity Index protocol (USEPA 2001). This system of using multiple indicators for maturity and stability came out of a true multi-party, multi-stakeholder effort to protect science and the credibility of the compost industry. It is disappointing that the US Compost Council has not addressedthis protocol.

RELEVANT TESTS RECOMMENDED:

Stability: Perform a volumetric respiration test- Solvita CO_2

Nitrogen stability: Perform the Solvita ammonia test (included with the Solvita compost).

Plant Effects: Cress Test in 25 and 50% compost:peat blend. Measure total biomass as percent of professional media control.

Nutrients and parameters: C:N ratio (must be below 25)

pH, Salinity: saturated paste test: rank the compost on severity index of 1-10, with dilutions required if salinity is greater than 2.0.

NH4:NO3 ratio. Nitrogen conversion should have been completed, so that the ratio of the two is expected to be less than 1.0.

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