MATURITY TESTING FOR COMPOST END-PRODUCT QUALITY CLASSIFICATION

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1. ABSTRACT

Two groups have composts have been evaluated for plant performance. In the first group, we prepare compost media for container plants using material of varying maturity and examine oxygen levels and other traits during growth of sorghum-sudangrass, a fast growing cultivar. In another study, we select various composts from several compost facilities and compare Dewar self-heating test results to cress performance.

In container studies, only composts ranked very mature did not damage plant roots. Depletion of oxygen was moderate to severe for semi-cured and uncured composts. Compost cured for 250-days had similar performance as the control of commercial peat media.

We examine Dewar test results for 119 composts and find a significant relationship to cress performance, but only over a very narrow range of self-heating. Results indicate that initial tests such as VOA, CO2-respiration and Solvita correlated well with container plant growth, but Dewar results are useful only if the rating system of I - V is ignored and instead the maximum temperature (Tmax) is used in a more critical manner.

2. INTRODUCTION

Composts, which are still active or not fully composted, are considered to be immature and unstable, but the effects of immaturity on plant growth are poorly understood. Many unfinished composts show re-heating potential in the Dewar test (Brinton et al., 1995); however, it is not clear what relation if any exists between Dewar and plant performance. Other traits of unfinished composts include elevated levels of ammonia as well as volatile organic acids (Jourdan, 1988; Manios, 1989; Ionaotti, 1994). Many tests have been proposed to demonstrate compost maturity and instability (It"vaara et al., 2000; SEPA 1997; Reinikainen and Herranen, 2000).

Certain traits associated with immaturity of composts have been shown to cause unsatisfactory plant performance in controlled studies (Devleeschauwer et al., 1981; Lee, 1977; Lynch, 1977). We have shown, however, that the effects of several chemical compounds that result from immaturity are influenced by both pH and their concentration in the final soil-compost mix (Brinton and Tr"nkner, 1999). Therefore, to understand potential harmful effects of immature compost, the proposed end-use of the compost must be fairly well known.

There are, however, many uses of compost which involve high application rates, and under these circumstances plant performance problems from immaturity may be very likely. To predict these potential problems laboratory tests may be used. Yet, analytical description of maturity or stability, in order to be meaningful to compost users, must have a proven relation to the proposed end uses of the product. Our study examines the Dewar self-heating test (Jourdan, 1988) and container plant performance in relation to various test qualities of compost of varying age and maturity.

We have previously reported a survey of 712 compost samples that had a wide range of VOA (Brinton, 1998). VOA levels correlated both to the age of the composts and conditions of the composts, as well as to poor performance of wheat seedlings and to a lesser extent to cress seedlings. Confounding factors were evident in that salt content affected cress very highly whereas respiration rate of the media influenced both types of seedlings equally. It is apparent that the mode of delivery and the concentration of certain compounds and biological will significantly determine the quality of the end compost.

We speculate that oxygen depletion as a result of immaturity of compost used in formulating growing media appears strongly associated with plant negative effects. It is well known that oxygen in the root zone is essential for normal root. Plant roots under waterlogged or anaerobic conditions appear to have suppressed metabolism and greatly reduced ion uptake rates (Salisbury & Ross, 1978). Earlier work indicates that O2 concentrations of 5% or less in the root zone may directly cause dramatic loss of potassium absorption potential (Vlamis, 1944). Thus, it seems evident that immature composts used in heavy could exert an effect on oxygen supply that is appreciable enough to cause suppressed root development. In this study therefore, we examine specific traits of oxygen in immature composts and compare with test to predict maturity.

3. MATERIALS AND METHODS

3.1 Compost Samples for Plant Growth Studies

We prepared a set of container mixes by collecting compost from a commercial compost facility situated in Maine (44ƒ35', 70ƒ00'). Representative samples were taken from each of three phases of the compost process; Phase I, "Uncured" after 21-days intensively turned composting; Phase II, "Semi-Cured" after the compost has been cured for 60-days; and Phase III- after the compost has been cured for a total of 250 days outdoors.

3.2. Composts for Dewar Study

To assess the relation of the Dewar self-heating test to plant growth, we selected randomly 119 compost samples from 28 different compost facilities that had a range of ages and evident maturity. These samples were transported to the lab overnight and immediately tested. The facilities included 34 biosolids composts, 42 leaf-yardwaste composts, 12 farm manure composts, 19 mixed-waste composts and 12 biowaste (food-waste) composts.

3.3. Analytical Methods Summary

Volatile fatty acids (VOA) were determined after water extraction and distillation in H_2SO_4 at pH 1.8, the resulting distillate being titrated to a standard endpoint (SMM, 1994). CO2 evolution rate was determined by modified Koepf-Isermeyer method with 40g fresh samples after 1-day equilibration with an incubation temperature of 34ƒC with CO2 trapped in NaOH-BaCl2 and titrated to HCl endpoint (Schlichtling and Blume, 1966). Total nitrogen was measured according to Kjeldahl procedure for solid waste (EPA, 1996) and nitrate by water extraction followed by liquid ion chromatography (SMM, 1994). Ammonia was determined by LiAC extraction followed by ion-electrode determination (Orion, 1995). Hydrogen sulfide presence was estimated by placing Merckoquant lead acetate indicator strips over acidified compost (Merck, 1996). Solvita maturity was determined with Solvita test kits (TMECC, 2000; Carlsbaek et al., 1999). Phytotoxicity tests were conducted on each of the three composts and one control by 1:1 (v/v) dilution of in limed, spaghnum peat (pH = 6.2) to obtain a conductivity of 2 dS m-1; subsequently, 10 seeds each of garden cress (Lepidium sativa) and wheat (Triticum aestivum var. Rose) were sown into each of six min-cells. Germination and growth is measured after 7 days. As a control we used Fafard 3-B professional media. For root measurements, plants were removed by slicing media cross-sectionally and washing with a gentle stream of water.]

3.4. Compost Test Traits

We analyzed these composts using standard methods and found the following traits (see Table 1):

Compost Type	pH 1:1	Org Matter % dm	Kjel-dahl-N% dm	Carbon: nitrogen	Am-monium -N ppm	Nitrate-N ppm	Volatile Organic Acids ppm	Salt dS/cm
Un-Cured Age 21 days	7.53	73.0	1.969	20.0	4872	1	2109	4.9
Semi-Cured Age 76 Days	7.44	73.0	2.212	17.8	3295	1	993	4.2
Cured Age 250 d	6.10	57.0	2.949	10.4	16	1734	319	4.5

Table 1: Physical / Chemical Traits of Compost Used in Container Plant Study

Sample Type	CO2-C% of C	CO2-C% of TS	Sol-vita Test	Wheat-Germination%	Wheat Rel. % Bio-mass	Cress Germination %	Cress - Rel.% Biomass	Dewar Tmax Cƒ - Grade
Un Cured	0.53	0.20	4	93	62	45	41	31 - II
Semi Cured	0.59	0.23	4	93	56	35	37	10 - V
Cured	0.14	0.04	7	93	83	98	79	3 - V

Table 2: Biological Traits of Composts Used in Plant Study

The results indicate material undergoing a rather typical chemical-biological transition from unstable, high ammonium, medium-high CN composts to low CN, high nitrate composts typical of finished materials. The Dewar reheating test gave a wide range of heating, yet the scale employed to rate the Dewar results indicated that both the Semi-cured and the Cured belonged to a "finished" class. In contrast, both the laboratory CO2 respiration tests and Solvita volumetric tests ranked the two lesser-cured samples into a similar class. We have speculated that the Dewar test may be insensitive for partially mature compost, particularly if the German system of rating is employed (Brinton, 2000; LAGA, 1984). VOA content was high for the uncured material and diminished as the material aged.

3.5. Container Mix Formulation

We made up container mixes by determining the needed dilution with peat moss to reach a suitably low conductivity of about 2 dS m-1 (TMECCb, 2000). The final media was a blend of compost + peat+ / washed sand (2 :1 : 1 v/v/v) that resulted in uniform air porosity from top to bottom of the containers after filling and packing. We duplicated the tests and ran two each of container volumes of 3 quart and 3-gallons.

A critical aspect of the study was to be able to measure oxygen concentration in the container media during growth. To do this, we inserted narrow vinyl air tubes to specified depths at the top, middle and bottom or 1.5", 5" and 8" depths from the top, respectively. These tubes could be attached to an O2 sensitive electrode via a mini-air sampler apparatus that requires only 5cc of air to get in a reading. The pots were seeded to fast-growing sorghum-sudan grass and harvests were made at about 20 days after planting.

4. RESULTS

4.1. Oxygen Levels in the Containers during growth

Oxygen concentrations in the growing containers diminished dramatically with depth and correlated closely with the apparent maturity of the composts (see Fig. 1). Similarly, oxygen levels in the containers during the course of the study did not vary appreciably (see Fig 2.) Uncured composts caused relatively low in oxygen in containers throughout the study. These apparent levels of oxygen correspond closely to the relative growth differences observed for tops and roots of the plants.

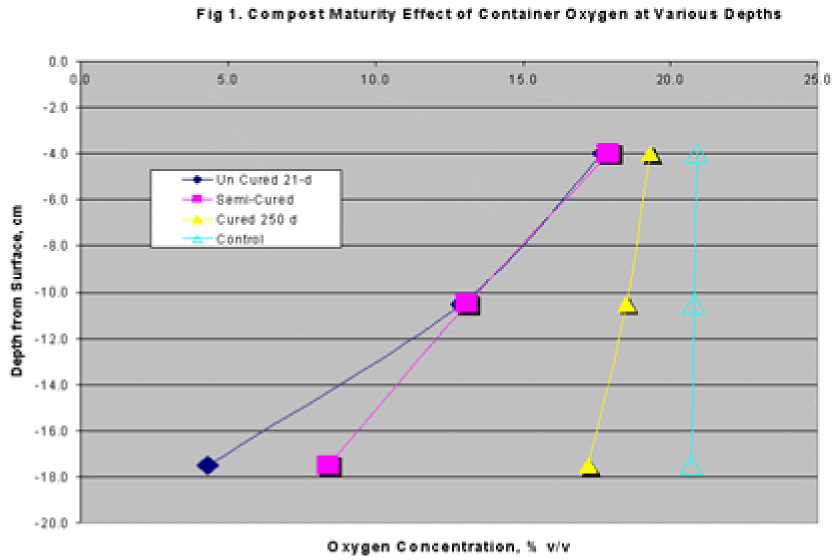

Figure 1 Compost Maturity Effect of Container Oxygen at Various Depths

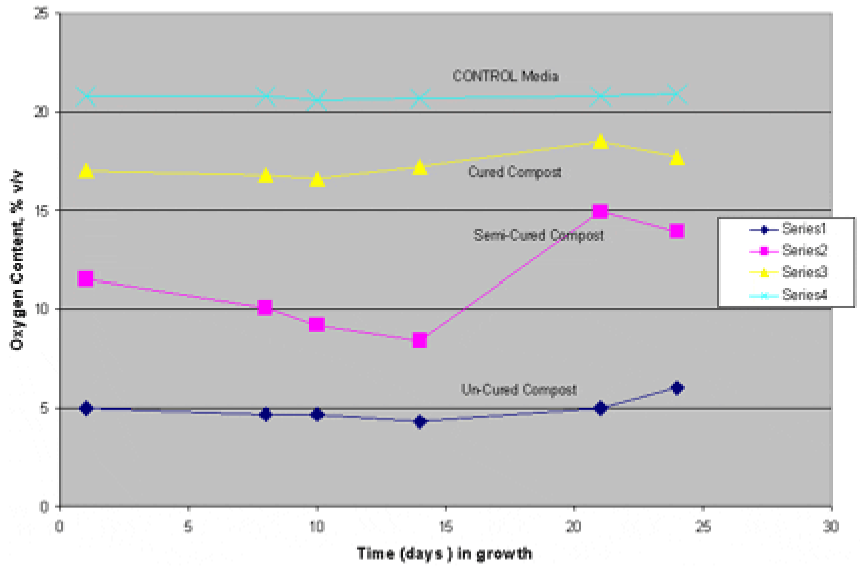

Figure 2 Oxygen Content in Container Composts over Time as Influenced by Maturity

4.2. Performance of Plants

Growers routinely remove plants from pots to observe the quality of root ball. At day 21, we pulled the plant/root mass for examination (see Fig 3). Root development and plant yield reflect the level of maturity and oxygen content of the compost media. The differences between the Uncured and Semi-Cured were more pronounced than between the Cured and the Control. Yet, the difference in Dewar rating of the uncured and semi-cured was very slight.

There was very little root growth visually apparent in the immature compost, and actually, when breaking open the media, we found that the rootlets were mostly confined to the top and edges of the container, the only places where oxygen is found. In the Cured treatment, the roots extended to the bottom of the pot.

We also harvested the rootlets from the containers by gently washing from the compost-peat-sand mix. There was clear evidence of rootlet damage sustained as a result of immaturity in both uncured and semi-cured composts. We tabulated the average root length and separated the tops, which were weighed. The following table gives the respective results for plant fresh weight and root length (Table 3).

Variable	UnCured	Semi-Cured	Cured	CONTROL
Plant Fresh Weight, mg.	73 a	116 b	183 c	196 c
Root Length, cm	7.5	9.0	12	19

Table 3: Yield and Root Weight in Relation to Compost Treatment.
Means followed by the same letter in the row do not differ significantly at the p ã 0.05 level

The plant effects observed in the immature composts indicated pronounced stiffening and thickening of the rootlets above the hypocotyl as well as discoloration of the rootlets. We detected hydrogen sulfide in un-cured and semi-cured compost media at the 17cm depth.

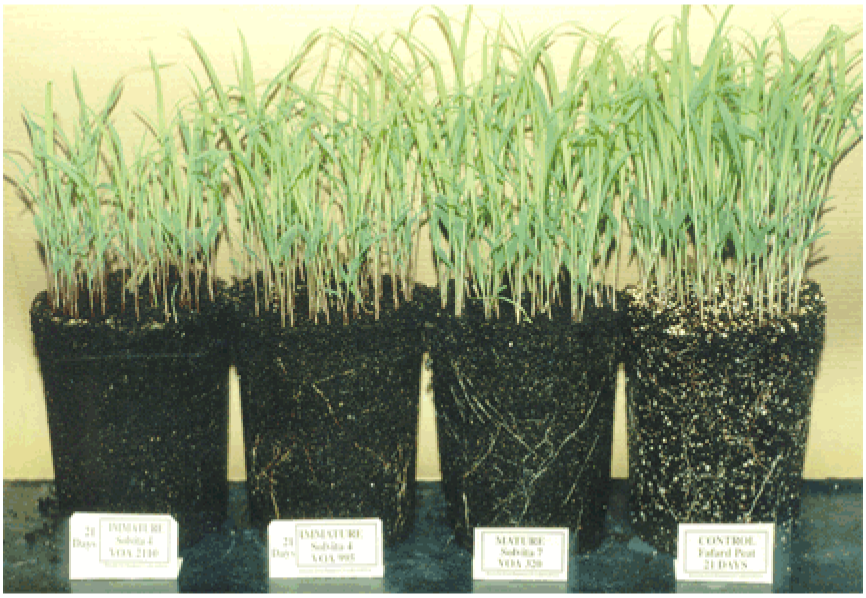

Figure 3 - Plant Growth in Relation to Compost Maturity

4.3. Container Plant Performance in Relation to Container Size

If oxygen concentration in the media affect plants, we asked also if plant damage would be also dependent on container size. This could be so due to diminishing surface: volume ratio with larger containers, potentially causing the potential negative effects of oxygen depletion to become more pronounced. Data for plant growth in three sizes of containers is as follows:

Container Size	Vol: Area Ratio cc:cm	Un-Cured	Semi-Cured	Cured
12-Liter	19	45	62	100
3-Liter	14	34	71	100
50cc	4	51	67	100

Table 4: Plant Performance in Dependence on Container Volume

These results provide little evidence for a difference when comparing the medium and large containers (3-Liter versus 12-Liter). The negative effect of the uncured compost was only slightly less pronounced in the very small speedling cells. While it is surprising that the differences are not greater between the containers, we do not know whether with even larger pots the effects would not be more pronounced. The damaging effects observed for the immature compost appear to be very substantial.

Surprisingly, there was no evident VOA remaining in the container mixes (< 500ppm) at the end of the growth period. Thus, the damaging effects seem to be very persistent and once an immature high-oxygen depleting compost is put into a container, it is not likely to improve adequately in the relevant time frame to cause a reduction in the negative effects.

4.4. Relationships Between Measured Parameters

These results have indicated that several of the initial tests were useful for predicting the potential plant problems observed from various levels of immature composts. Among the significant relationships were VOA versus root length and plant yield versus oxygen levels. Furthermore, laboratory CO2-rate measurements, and Solvita volumetric CO2-tests closely predicted seedling test results with cress and wheat.

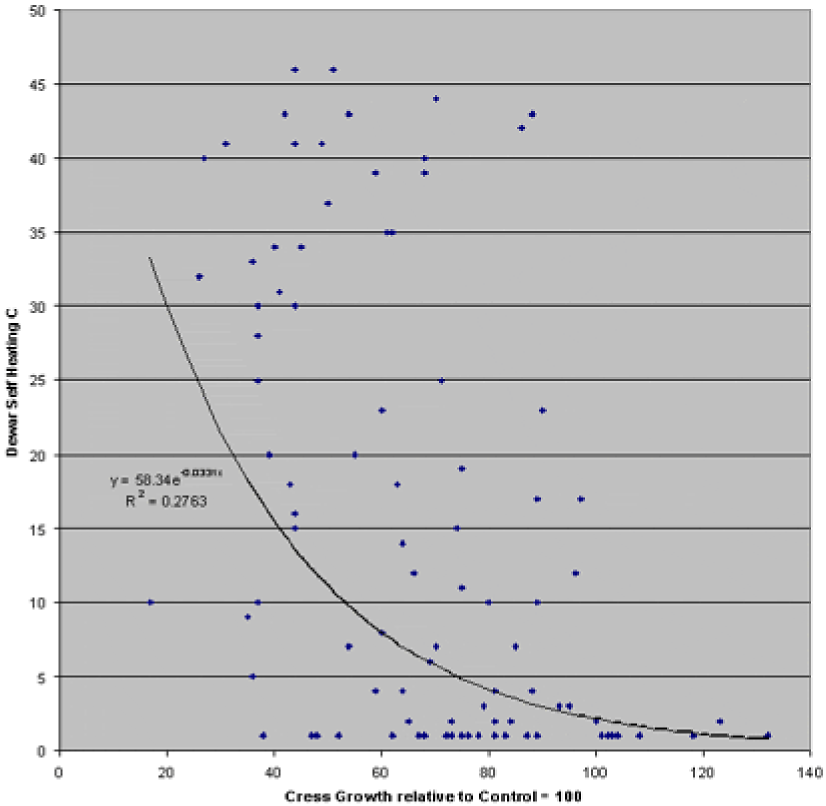

Figure 5 Dewar Self Heating vs. Cress Weight at 7-Days

In order to look more closely at Dewar values, we examined 119 samples of compost

for Dewar Tmax versus performance of cress seedlings at day 7. The results are shown in the following graph (Fig 5). The best fit, using an exponential equation, gave an r=0.53**. While the relationship is significant, what is noticeable is that the Dewar test appears to be skewed so as to be a very poor indicator of plant growth. Small amounts of Dewar heating may correspond to significant plant growth reduction. Thus, in or study, a Dewar rating of V (0-10C Tmax) covers a range of plant growth performance of 100 down to 55%. However, the Dewar test may predict performance when only the temperature (Tmax) is used instead of the rating of I-V. Thus, it would be appropriate to modify how dewar tests are interpreted. A mature compost would be classed as 0-5C, curing from 5-15C and active as 15-25. Any compost heating more than 25C in a Dewar is likely to be extremely immature and phytotoxic.

These findings overall suggest that a number of important, interrelated factors play a role in determining plant effects arising from immature composts. The causal interconnected causal parthways most likely begin with elevated CO2 evolution translating into elevated VOA. While effects from VOA and ammonia may be stronger early in growth at root-emergence, the oxygen deprivation and hydrogen sulfide effects may be longer lasting or occur later during growth While these observations suggest that maturity is a complex phenomenon in terms of causal mechanisms, several test traits we employed accurately predicted the resulting problem conditions that were observed in container growth.

5. Acknowledgment

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