

Relationship between Respirometric Stability and Agricultural Maturity in Compost from Municipal Solid Waste

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ABSTRACT

Composting of the Organic Fraction of Municipal Solid Waste (OFMSW) has become an increasingly widespread practice in many countries today. The final product, compost, must be stabilized and sanitized if it is to be used as an input of organic matter and nitrogen in agricultural soils without adverse effects. Respirometric determination of the Oxygen Uptake Rate is one of the most widely accepted methods in the literature for measuring the development of the composting process. This method allows the *stability* of samples taken during the composting process to be determined. On the other hand, mature compost is defined as the product which has no negative effect when it is applied to agriculture. Mature compost is often evaluated by means of germination or growth tests of plant species. In this paper we have studied the relationship between the two concepts and measurement techniques to evaluate the possibility of predicting *maturity* by means of determining *stability*. To this end, samples from two types of OFMSW compost were analyzed at different composting times through an assay of tomato seed germination and the degree of stabilization was determined by the SOUR respirometric method (Specific Oxygen Uptake Rate). Two other OFMSW compost samples were studied through assays of *Latucca sativa* growth using the *Di.Pro.Ve.* method developed at the University of Milan. The test was performed at different composting times and degrees of stabilization. In light of the results of the respirometric method and the growth and germination efficiency, we were able to correlate both variables (*stability* and *maturity*). We have found that by determining compost *stability* by means of a respirometric technique, we can obtain a good indicator of the *maturity* of the product and therefore predict its agronomic performance.

Keywords: composting, germination test, growth test, OFMSW, SOUR

INTRODUCTION

The increased production of ornamental crops and nursery plants in recent years has led to a sharp decline in *Sphagnum* peat reserves worldwide (Handreck and Black 1991). *Sphagnum* is a highly porous material with an extraordinary moisture retention capacity and a large *quantity* of mineral elements that are essential for plant growth. The largest reserves of *Sphagnum* can be found in Canada, Russia and countries of northern and central Europe. Practically all of the peat consumed in the world is used for agricultural purposes, chiefly in nurseries and as an organic soil amendment in lawns, golf courses and home gardens (Evans and Stamps 1996). Peat is also used as a wastewater filtering agent and fuel (Björnbom *et al.* 1991; Selby and Mark 1986). However, rising market costs due to the diminishing reserves of peat and the outsourcing of this product means that alternatives to peat must be sought. Among the main options is the recycling of organic wastes, which would also contribute to mitigating another important problem: the unstoppable growth in the dumping of organic matter in landfills. In turn, this would aid in preventing contamination as it would lower the emission of greenhouse gases and highly contaminant lixiviates, as well as reducing the need for landfill.

Through composting, the organic matter contained in garbage is decomposed in aerobic conditions at high temperatures. In a composting process well-conducted, temperatures reached around 40°C in the first 24 hours and about 65°C at the end of first week. These temperatures are necessary for proper sanitation of the final product against pathogenic microorganisms present in municipal and animal wastes and (Feachem *et al.* 1978; Vinneras 2007).

Thus producing an organic amendment for soils which

is highly porous, rich in nutrients and humic substances and capable of immobilizing significant amounts of carbon in soils which would otherwise be transformed into carbon dioxide or methane gas, thus contributing to global warming. Compost can also be employed as a fertilizer, making it apt for use in agriculture, nurseries and greenhouses where the use of peat substitutes is greatly limited due to their lower absorption capacity.

However, one of the main drawbacks to using compost lies in the difficulty of ensuring its *stability* and *maturity*. *Stability* is determined by the microbiological activity that remains in the product. High biological *stability* can be defined as the state at which the organic matter shows low microbiological activity under optimal conditions (Iannotti *et al.* 1994). On the other hand, compost *maturity* is a term used in the field of agronomics which is directly related to the level of toxicity of the material applied to the land (Spohn 1978). *Maturity* and *stability* are two different concepts as exemplified by the fact that sludge may show low biological *stability*, but pose no phytotoxic effects.

The need to determine the quality of the end product, or to estimate the time required to obtain it, has led to the development of methods to determine the remaining biological activity of the waste and its evolution. These are respirometric techniques that permit the biological activity of waste to be determined based on the oxygen consumption estimated by the microbial community contained in the sample as the organic matter decomposes. On the other hand, the potential for using compost as a crop substrate in greenhouses has led to methods to evaluate the *maturity* of plant response for this product. To evaluate the *maturity* of a material we can either establish a direct relationship between its content in xenobiotic agents as polycyclic aromatic hydrocarbons (PAH), polychlorinated dibenzodioxins

(PCDD), polychlorinated dibenzofurans (PCDF) and phytotoxic intermediate metabolites that appear during decomposition, or we can measure the effect of the material in controlled experimental assays. The germination tests of Zucconi *et al.* (1981) and Castillo *et al.* (2004), or the plant growth tests of Nappi *et al.* (1992) and *Di.Pro.Ve.* (BURL 2003) are examples of assays that have been proposed to determine *maturity*. These methods have as their aim to ensure successful horticulture practices by determining the seed germination percentage or plant weight (aerial or radical parts of the plant). The absence of phytotoxicity is determined by a similar germination index or by developments that are similar to those produced by the control. For this purpose, it is common to select certified seeds with a guaranteed germination level in specific conditions.

The relationship between *stability* and *maturity* is evident; however, due to the difficulty of determining *stability* in a reliable and fast manner, the relationship between these properties has not been studied. Previous literature relating these two variables is oriented more towards ensuring the sanitation of the product by different methods than towards establishing a relationship between both properties (Mari *et al.* 2003).

The aim of this research is to seek a relationship between product *stability* as determined through the SOUR respirometric method and product *maturity*, which is evaluated by means of two methods: germination of tomato (*Lycopersicon esculentum* Mill. cv 'Atletico') and growth of lettuce (*Latucca sativa* L. cv 'Augusta'). Four types of compost were studied in total. To determine stabilization time and maturation of the product, variables of *stability* and *maturity* are studied at different composting times.

MATERIALS AND METHODS

The four types of compost used in the research correspond to two different composting plant treatment schemes. Compost types A and B (Table 1) correspond to an Organic Fraction of Municipal Solid Waste (OFMSW) with similar characteristics that was composted using a turned windrow system in Cordoba, Spain. The evolution of product *maturity* was studied by taking three samples from both types of compost at three different moments of fermentation. *Stability* was determined much more frequently than *maturity*: on a weekly basis in compost A and every three weeks for compost B until the product was refined.

Compost types C and D (Table 1) were of similar characteristics and correspond to an OFMSW with a high proportion of green wastes. Both were composted in two plants located in the metropolitan area of Milan using high-performance systems (forced aeration tunnels with forty-day maturation in aerated piles). The evolution of product *stability* and *maturity* was studied by taking samples of both types of compost at the end of the tunnel and following 40 days of maturation.

To correlate *stability* and *maturity*, two methods for evaluating *maturity* were examined. Composts A and B were evaluated following a method similar to that proposed by Castillo *et al.* (2004). Composts C and D were evaluated according to the method proposed by the *Di.Pro.Ve.* group, to evaluate phototoxicity in the Lombard region of Italy. The SOUR test was used to measure *stability* in both cases. By comparing these methods, it is possible to obtain information which allows us to determine which method is best for evaluating *maturity* and which is most closely related to *stability*; a variable that can be measured quickly in the laboratory.

Table 1 Initial characterization of wastes.

	Compost A	Compost B	Compost C	Compost D
Composition	100% OFMSW		60% OFMSW +40% Green Wastes	
Organic matter (%)	39.3	39.4	76.8	75.1
C (%)	37.1	29.5	42.5	42.3
N (%)	2.1	1.5	1.7	1.6
C/N	17.6	19.6	25	26.4
pH	8	6.6	5.2	4.9

In what follows we describe the methodology of the three techniques examined in this paper.

SOUR method

Many papers report the biological activity of the composting process in terms of the oxygen uptake rate (Lasaridi and Stentiford 1998), the respirometric index (Adani *et al.* 2001) and the respiratory quotient (Gea *et al.* 2004). Although the SOUR method is a well-known concept in the scientific community, its value depends on different variables, making it necessary to standardize the method. In this paper, the method has been standardized following the BOD method (ISO 5815:1989).

In the SOUR method, the activity of organic matter is evaluated according to changes in oxygen concentration with time. This procedure involves measuring the dissolved oxygen concentration over time in an aqueous solution and determining the amount of oxygen consumed per unit of time and volume ($\text{mg O}_2 \cdot \text{L}^{-1} \cdot \text{h}^{-1}$). The slope value provides a first value that is known as the oxygen uptake rate (OUR). Once the percentage of total and volatile solids in the sample is known, the OUR in $\text{mgO}_2 \cdot \text{gVS}^{-1} \cdot \text{h}^{-1}$ at a given time is determined. The SOUR (the maximum value of the OUR) is used as a control parameter to compare the degree of stabilization of the waste.

The SOUR was determined by following the changes in oxygen concentration over time in a suspension of 1-5 g (wet weight) of compost in 1000 mL of distilled water. Oxygen concentration was determined using a membrane-covered, polarographic, Clark-type dissolved oxygen probe linked to a PC through an oximeter and a controller. The suspension was continuously stirred by means of a magnetic stirrer (to 300 rpm) and periodically aerated using a laboratory air line to replenish the oxygen consumed. The consumed oxygen was replenished using software developed by our team. This software sends an order to the electrovalves to permit the air to flow when the oxygen falls under a given value (6.8 mg O_2 in most cases for a test at 30°C) in order to guarantee an oxygen concentration of between 7.2 and 6.8 mg/L . Double diffusers were used to improve the transfer of oxygen to the medium. A water recycling system was added to prevent liquid haulage when the air is bubbling.

The dissolved oxygen concentration data, which are expressed in mg/L , were analyzed using LabView to calculate the slope and the curve integral between 0 and 20 hours. This respirometric technique and its indexes (SOUR and cumulative oxygen demand, OD, measurements in the liquid phase) prove to be an excellent solution for determining compost stabilization (Carmona 2004).

Plant germination test

This test was conducted in greenhouses at the University of Cordoba and applied to two different types of compost produced by means of a turned windrow system at two composting plants located in the province of Cordoba (Spain) that use similar raw materials. Temperature and moisture variables were controlled in the greenhouse. Temperature was maintained at 18 and 28°C (at night and during the day, respectively). The compost was watered twice daily using fog atomizer sprayers to achieve a relative humidity of above 40%. All of the experiments were performed in industrial greenhouse nurseries using greenhouse trays comprised of 150 cells measuring 57 cm^3 . The result of the germination is the mean value of 50 cells in which the compost is used as substrate with different degrees of maturation. Another group of 50 cells was reserved for planting the control seeds in a white peat (60%) and black peat (40%) base. A product mineralization more advanced characterizes black peat. While the white peat contains 90% organic matter, black peat contains 55%. The second major difference is the apparent density, while the first is less than 0.1 $\text{g} \cdot \text{cm}^{-3}$, black peat has a density of about 0.3 $\text{g} \cdot \text{cm}^{-3}$. However, nutrient extractables content is very similar for both peats, around 130 $\text{mg} \cdot \text{L}^{-1}$ for the basic nutrients, nitrogen and potassium, and 20 $\text{mg} \cdot \text{L}^{-1}$ for phosphorus.

As a result of deficiencies in the substrate over time (chiefly due to its lack of structure, compaction and high electrical conductivity), we decided to dilute the assay substrate with white peat, thus producing an assay mix composed of 60% white peat and

40% compost. By introducing these modifications, the mix meets the physical and chemical property requirements for its use as a greenhouse substrate (Verdonck 1998; Noguera *et al.* 1997). The physical characteristics were as follows: high moisture retention capacity (20-30%), low density ($< 0.4 \text{ g cm}^{-3}$), high porosity ($> 85\% \text{ v/v}$), fine texture and stable structure. The chemical properties were as follows: high cationic transport capacity ($> 20 \text{ meq/100 g}$), high nutrient content (40-199 ppm N-NO_3^- , 3-10 ppm P, 6-249 ppm K^+ , 8-200 ppm Ca^{2+} , 30-70 ppm Mg^{2+}), low salinity, slightly acidic pH (5.2-6.3) and high buffering capacity.

A species with an average tolerance to salinity following FAO guidelines was selected: tomato (*Lycopersicon esculentum* Mill. cv 'Atletico'). Tomato seeds were planted in a substrate composed of 40% compost and 60% white peat in order to evaluate the phytotoxicity of the compost at different days of fermentation through plant response rather than through the improvement capacity of the compost (Castillo *et al.* 2004).

Although germination began at around 7 days, in order to obtain the results of the evolution of germination, data were recorded periodically up to day 40, after which time germination remained unchanged. The results of germination, expressed in terms of the germination index (GI), were examined by analysis of variance to determine any differences with respect to the germination of the control.

$$\text{GI (\%)} = \frac{\text{total number of seeds germinated in the experiment}}{\text{total number of seeds germinated in the control}} \times 100$$

Di.Pro.Ve. plant growth test

The *Di.Pro.Ve.* plant growth test is a *maturity* test developed by the *Dipartimento di Produzione Vegetale* at the *Università degli Studio de Milano* according to the normative method in that country (Bolletino Ufficiale della Regione Lombardia 2003). The test was applied to two different types of compost produced by high performance systems at two composting plants located in the city of Milan (Italy) that use similar raw materials. In this case, the variable studied is plant growth, using the dry weight of the aerial part of the plant as an indicator. Due to the fact that plant growth is positively related to the presence of nutritive elements and negatively related to the presence of surplus elements and/or toxic substances, this method evaluates the phytotoxicity of the generated compost due to growth inhibition rather than germination (Astori 1998; Herrera *et al.* 2008). The method was carried out on *Latucca sativa* L. cv 'Augusta', which is very sensitive to metabolites produced by phytotoxicity. Plant growth, in dry base, was compared to the control in a sand, clay, loamy soil and peat base.

The method involves reproducing a substrate similar to that of soil which is comprised of the following components: sand (87.5%), clay (9%), loamy soil (2%) and peat (1.5%). Forty kilograms of substrate were prepared in an approximately 30-liter container in order to obtain a perfect mix. To achieve optimal growth, an N-P-K fertilizer solution was added. The solution was obtained as follows. In a 1000 mL flask, transfer 0.115 g of Ca (H_2PO_4)₂, dissolve with 700 ml of distilled water, add 0.655 g of (NH_4)₂SO₄ and 0.308 g of K₂SO₄, redissolve and fill to top. The ratio of fertilizer is 40 mL:kg of substrate to obtain a sufficient amount of prepared solution to fertilize 25 kg of substrate.

The sample to be assayed must be used in this form, that is, without drying but passed through a 10 mm sieve in order to separate unsuitable, large or undesirable elements. Plastic containers of approximately 500 cc are used for the plant assay. 250 grams of prepared substrate and the appropriate amount of sample are placed in the containers. To extrapolate the amounts used in the laboratory to the agricultural scale, we use the standard soil density (1.51 g/cm^3) and a soil depth of 30 cm, which is considered the arable layer. Five doses ranging from 4.4 to 20 g/kg of dry substance were assayed, as well as the control comprised exclusively of prepared substrate. The quantities assayed in the laboratory are equivalent to agronomic quantities ranging from 19.9 to 90.6 tons/ha.

Following this step, the previously germinated lettuce seedling is transplanted to a plastic tray. To do so, the seeds are distributed over 1 cm of moist sand and covered with a similar amount of sand. The tray is then covered with plastic and exposed to the

sun. After 48 hours, the first cotyledons are produced and the seedlings are ready to be transplanted. Four plants are transplanted to each of the cells and placed in the controlled growth chamber or in the greenhouse. Temperature conditions must be maintained at a constant level throughout the testing period to ensure optimal conditions for plant growth (16 hours of light, 25°C during the day and 16°C at night). Water lost through evaporation must be replaced daily by adding distilled water in order to maintain the substrate at approximately 80% of its water retention capacity.

Two weeks after transplanting, the plants from each cell are harvested by cutting the aerial part of the plant. The fresh weight is then determined, followed by the dry weight of each cell by drying at 105°C. The growth index (GI) is defined as the production of biomass measured according to the dry weight of the epigeal part of the plant and is expressed in terms of plant grams per cell with respect to the control. Data on the fresh and dry weight of each cell are used to calculate the mean weight of each cell and the standard deviation. The data are then compared statistically using ANOVA. The result can be expressed in the form of a table showing the mean data of production for each dose and indicating if there are significant differences, or by means of a dose-effect graph where the x-axis represents the dose in g/Kg or g/ha and the y-axis reflects production as expressed by the growth index.

RESULTS AND DISCUSSION

Study of maturation using germination test

Although the specific oxygen uptake rate (SOUR) is widely employed as the best indicator of stabilization in the composting process, daily accumulated oxygen consumption can also be used (Lasaridi and Stentiford 1998; Chica *et al.* 2003). **Fig. 1** shows the evolution of SOUR with respect to the composting time of compost A. Analogously, although

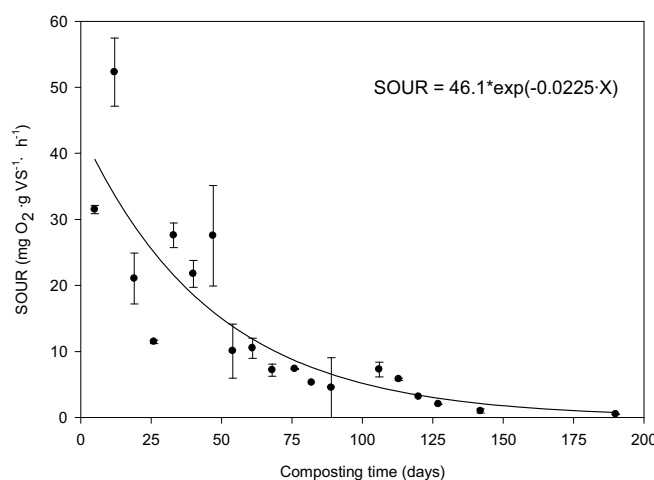


Fig. 1 Evolution of stability in compost A.

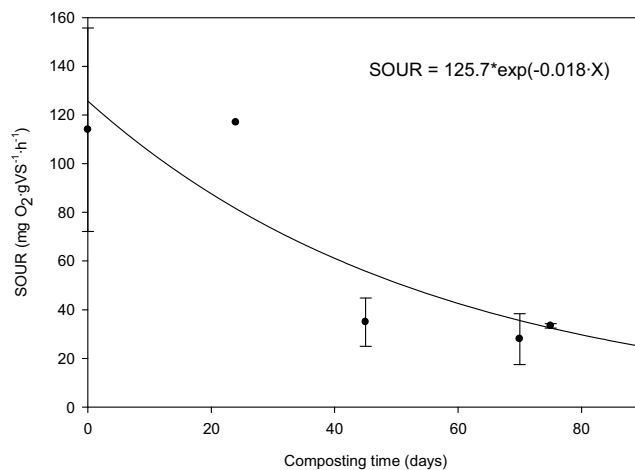


Fig. 2 Evolution of stability in compost B.

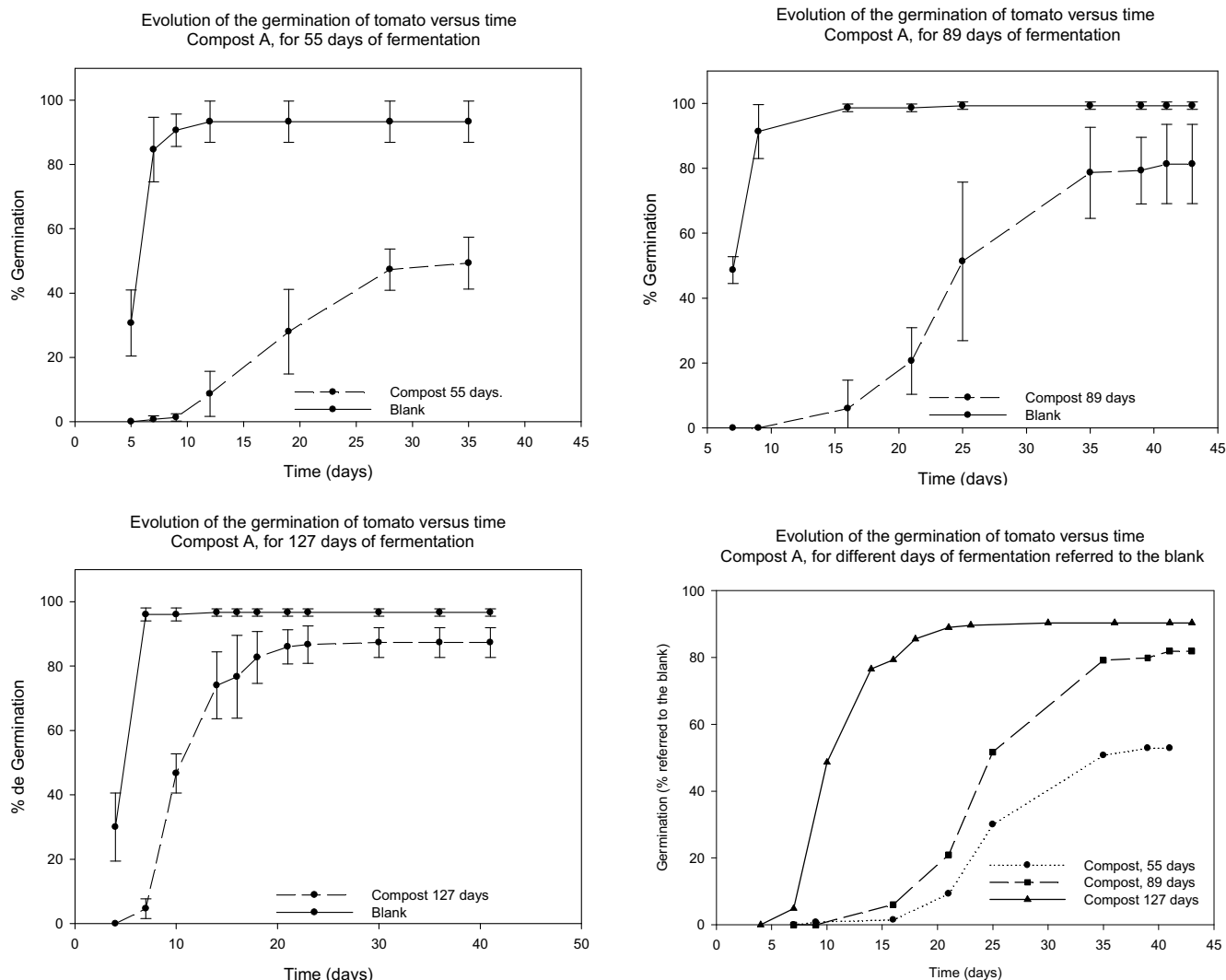


Fig. 3 Characterization of compost A produced in Cordoba using a turned windrow system at different stages of fermentation.

with fewer data, Fig. 2 shows the results for compost B. Figs. 1 and 2 show that this variable evolves according to a first-order exponential; typical of simpler processes to decompose organic matter (Keener *et al.* 1993; Mohee and White 1998; Hamelers 2002).

Knowledge about product stability is as or more important than knowledge about product maturity. However, these assays often involve a large effort in operational terms as well as a long waiting time before obtaining results. Due to the fact that results are obtained immediately when measuring stability (just a few hours) and given that these two qualities of organic matter are closely related, it would be interesting to find a positive relationship between both in such a way as to infer maturity via stability. To do so, we have selected three intermediary moments of fermentation (at days 55, 89 and 127) for the compost A produced in Cordoba by means of a turned windrow system, and another three moments of fermentation for compost B, which was also produced in Cordoba using a similar turned windrow system (days 24, 45 and 70). The aim was to study low, medium and high stability values for each type of compost. However, these points served to analyze the high stability range for compost A (Fig. 1, SOUR values below 10) and the very low stability range for compost B (Fig. 2, SOUR values between 120 and 30).

Fig. 3 shows the results of tomato germination for compost A at days 55, 89 and 127 of fermentation. All of the samples proved to be significantly different from the control germination with $p > 0.05$; data that can be considered reliable after day 25 of the assay. This result indicates that fresh compost, or immature compost, has a twofold effect on the

plants. Firstly, it greatly inhibits germination; and secondly, it delays germination time.

For a clearer comparison of the results, the last representation (D) in Fig. 3 shows the germination percentage with respect to the germination of the control, which is considered the maximum germination that can occur in optimal substrate conditions. For the tomato with less stable compost (55 days), the test reveals that a maximum germination percentage of 50% is obtained by day 40 of the assay. For the 89-day compost, a maximum germination percentage of 82% was reached at day 35. The 127-day compost achieved a germination percentage of 90% by day 20 of the assay. It should also be noted that the compost, with four months of treatment, produces almost no delay in germination and performs in a very similar to the control substrate (white peat + black peat), although it is statistically different. Substantial differences were not found between the final germination percentage of the compost fermented for 89 days and the compost fermented for 127 days (more than 80% of the total in both cases), although there is a clear delay in germination with the younger product.

Table 2 Characterization of Compost A.

Compost A	55 days	89 days	127 days
GI Tomato (%)	52.8	81.9	89.7
SOUR (mg O ₂ ·gVS ⁻¹ ·h ⁻¹)	10.1	4.5	2.0
T _{max} self-heating (°C)	60.6	45.3	20.4
pH	8.17	8.38	8.74
Conductivity (µS/cm)	1602	1503	1180
Organic Matter (%)	45.6	38.0	23.7

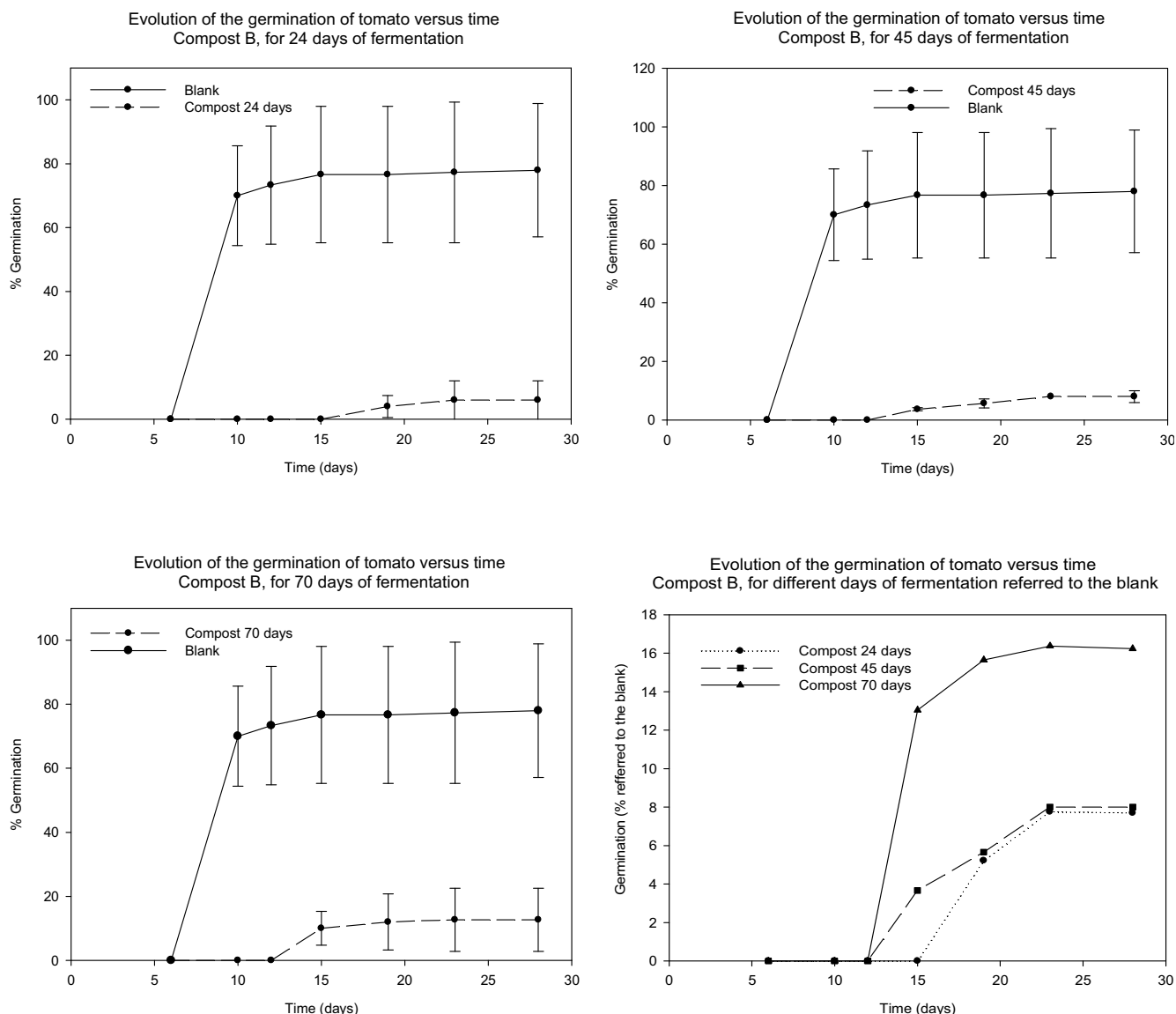


Fig. 4 Characterization of compost B produced in Cordoba using a turned windrow system at different stages of fermentation.

Table 2 shows the values of some variables which characterize the sampled product, among them the GI mentioned above.

The proper decomposition of the organic matter, a reasonable increase in pH, and a decrease in biological activity as shown by the self-heating test and the SOUR during the six-month composting process, guarantee a higher germination index. As we have seen, however, the better results obtained with the control using a peat mix base are not achieved.

Compost B, which was produced in another plant in the province of Cordoba, shows substantially higher values in terms of biological activity than those found for the previous sample with the same composting time (see **Figs. 1** and **2**), leading us to predict that the difference in *maturity* will also be more evident. When observing the SOUR vs. Composting Time curve (**Fig. 2**), it is clear that if *stability* and *maturity* are related, then the germination of tomato should be notably lower.

When analyzing the results of the three stages of fermentation (24, 45 and 70 days), we find that none of the three obtain germination results similar to those of the control (**Fig. 4**). Indeed, as can be seen in the summary figure of the three assays, the maximum value of the y-axis is below 20%.

Table 3 shows the value of some variables that characterize the sampled product, among them the germination index (GI) mentioned above. In light of the results, we can

Table 3 Characterization of Compost B.

Compost B	24 days	45 days	70 days
GI Tomato (%)	7.7	8.0	16.2
SOUR (mg O ₂ ·gVS ⁻¹ ·h ⁻¹)	84.4	34.8	27.9
T _{max} self-heating (°C)	61.3	58.1	46.6
pH	7.15	7.16	8.41
Conductivity (μS/cm)	2060	1938	1331
Organic Matter (%)	38.9	37.4	34.6

deduce that the process of decomposition of the organic matter is partially blocked in this system for some reason, since decomposition is less favorable. The high values of biological activity obtained by the respirometric analysis are quite notable and supported by the high temperatures reached by this product in the self-heating test.

Study of maturation using growth test

Using another *maturity* assay, on lettuce growth, with compost types C and D, we attempt to determine if the improvements incorporated into this test (standardization of operational conditions and presumably faster results), make this method a better indicator of *maturity* than the tomato germination test. While the minimum length of time needed to obtain data regarding germination was 25 days in the case of the growth test, in this case data can be recorded after

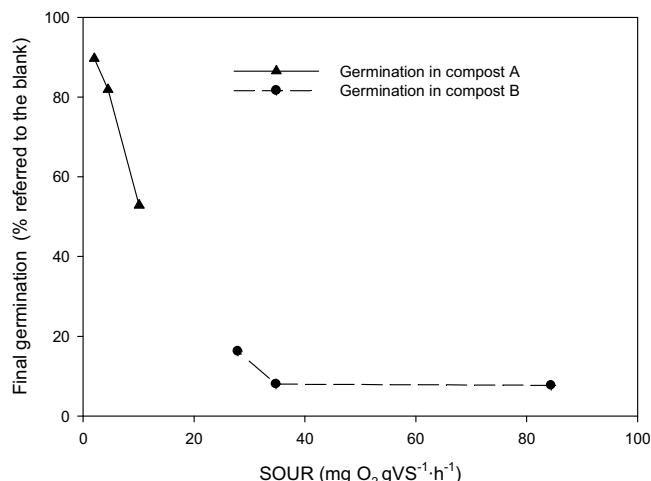


Fig. 5 Relationship between stability and maturity in compost A and B obtained with a turned windrow system.

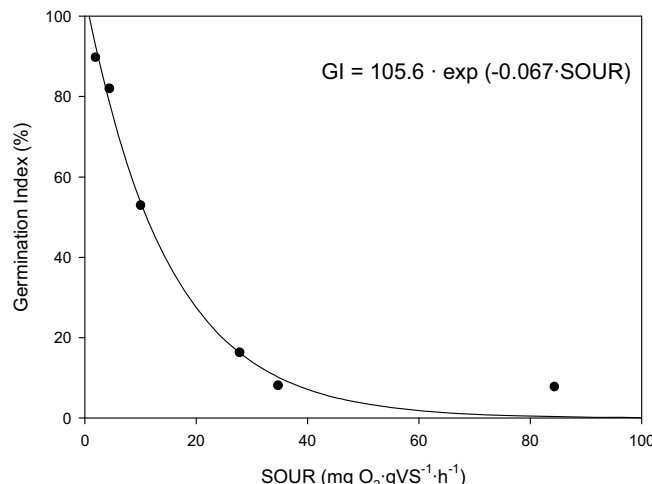


Fig. 6 Relationship between stability and maturity in compost A and B obtained with a turned windrow system.

Table 4 Characterization of compost C and D.

	Compost C		Compost D	
	Outgoing compost of tunnel	Compost with 40 days of maturation	Outgoing compost of tunnel	Compost with 40 days of maturation
GI Lettuce (%)	0.31	0.20	0.18	0.49
SOUR (mg O ₂ /gVS·h)	7.7	6.2	5.0	4.9
T _{max.} self-heating (°C)	52.8	56.3	49.2	38.9
pH	5.35	5.26	7.80	8.07
Organic Matter (%)	76.8	76.8	73.2	63.4

two weeks, the time at which the weight of the plant is sufficiently different to reveal deficiencies in the substrates.

Based on the study (Fig. 5) of these two substrates generated from a similar raw material, we find that the product is highly phytotoxic with tunnel residence times of around three weeks for both types of compost (C and D), since growth was significantly different from the control for the substrate inoculated with all the doses of compost. However, after 40 days of maturation in aerated windrows, significant differences begin to appear. While compost C remains as phytotoxic as it did at the end of the tunnel even for the most diluted dose of compost (19.9 t/ha), the doses of 19.9 and 30.3 t/ha in compost B show a significantly similar growth to the doses of the control, while worse results are found with higher doses. This demonstrates that although compost D does not attain the category of a completely mature product, it could still be used in small doses with certain restrictions.

Table 4 corresponding to the compost produced in Italy using a high-performance system reveal deficiencies in the composting plant where compost C was produced since the evolution of the organic matter was impeded and the pH level clearly indicates the phytotoxicity of the product. Due to the large proportion of green materials in these wastes, the product contains enormous amounts of organic matter (cellulose and lignin, which are difficult to biodegrade) in addition to being porous and having other beneficial qualities. Nonetheless, these do not improve the composting process at the plant where compost C was produced in which the process appears to be partially blocked (null evolution of organic matter, very low pH without evolution and a high self-heating capacity).

Comparison between Respirometric Stability and Agricultural Maturity

In line with the objective of this study, Fig. 6 shows the germination percentage for each of the samples taken from compost A and B compared to the real value of biological

activity for each sample at the time it was used as a substrate. The following information can be drawn from the graph. First, the data are grouped into two different series: data from compost A corresponding to low values of biological activity, high stability and therefore a good level of maturity; and data from compost B which are grouped in a range of high biological instability and therefore reveal low or null maturity.

Given that both products were originally taken from a similar material and the germination conditions have been the same, it follows that both groups form a single series of data spanning low to high levels of stability. In this case, we can fit the germination of tomato in compost to an exponential function that relates maturity as determined by this method and stability as determined by the SOUR method.

According to the relationship found by the tomato maturation test (Fig. 7), a product can be considered mature when germination is significantly equal to that of the control. In practice, this will always occur when the germination percentage is above 90%. Extrapolating this to the field of biological stability, this results in an approximate SOUR value of 2.5 mg O₂.gVS⁻¹.h⁻¹. This finding coincides in part with the data in the literature insofar as compost is considered to be stable when it shows a biological activity of 1 mg O₂.gVS⁻¹.h⁻¹ as measured by the SOUR.

The relationship found in Fig. 7 is an extraordinary tool for determining the maturity of compost in a short amount of time (4-6 hours).

The focus of this work is to seek relationships that can be used to compare maturity with a rapid method to determine stability in the laboratory. To achieve this goal, Fig. 8 relates stability and maturity for compost types C and D. However, the results do not permit us to draw concise conclusions due to the deficiencies in the composting process of compost C and to the low SOUR values which, compared to the high values for organic matter, indicate that the organic matter is not easily biodegradable. Thus, a measurement system such as the one used in this work (which determines the oxygen uptake rate due to fermentation under 20 hours) is not appropriate.

CONCLUSIONS

Two methods for determining compost maturity have been examined: germination of certified tomato seed and growth of lettuce. The results obtained for both methods using four types of compost produced by different systems and sampled at different stages of fermentation have permitted us to draw conclusions regarding the differences in the quality of each type of compost, thus validating the utility of both methods.

The correlation of these methods with the SOUR me-

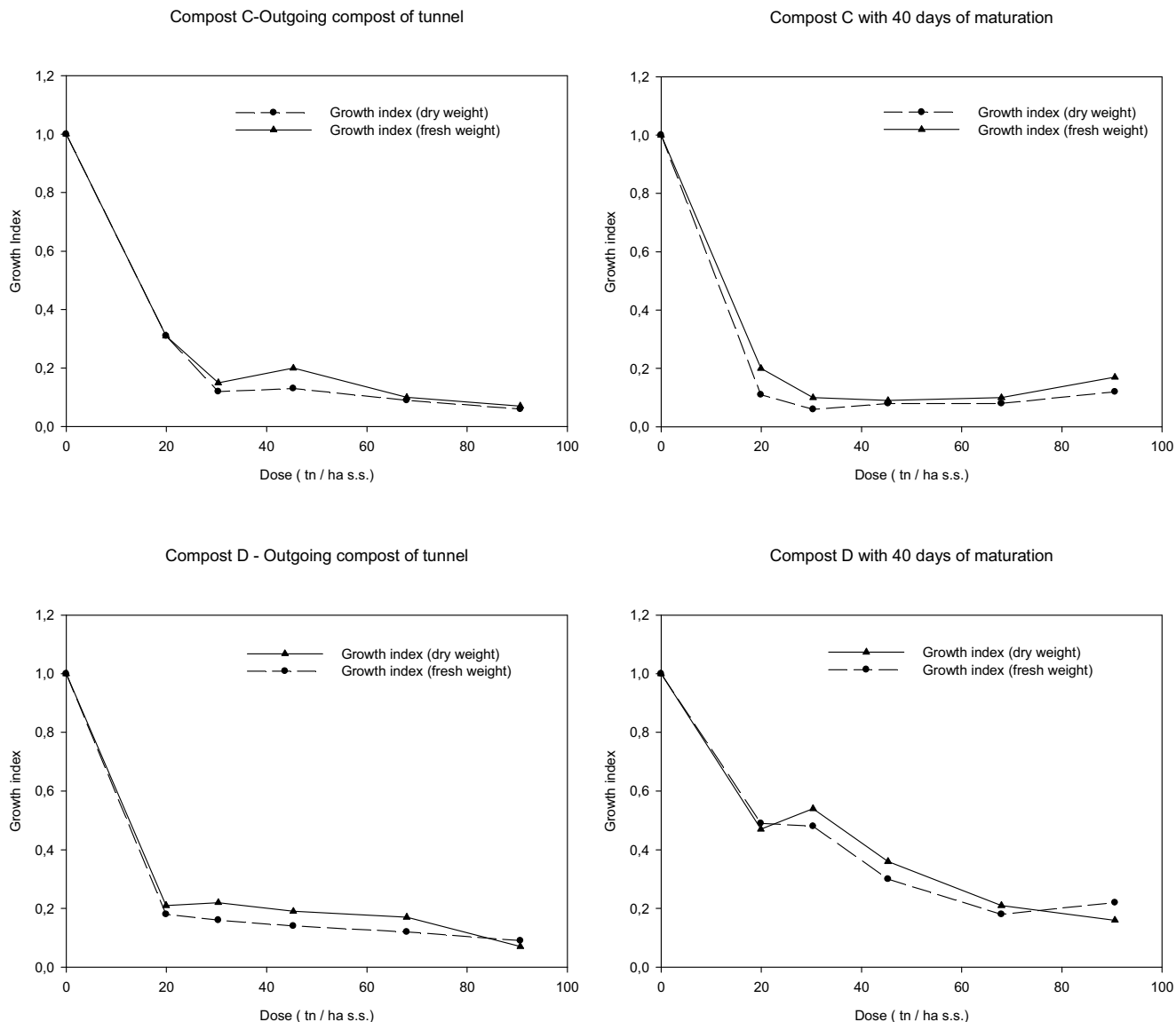


Fig. 7 Characterization of the compost produced in Sesto and La Spezia using a high-performance system at different stages of fermentation.

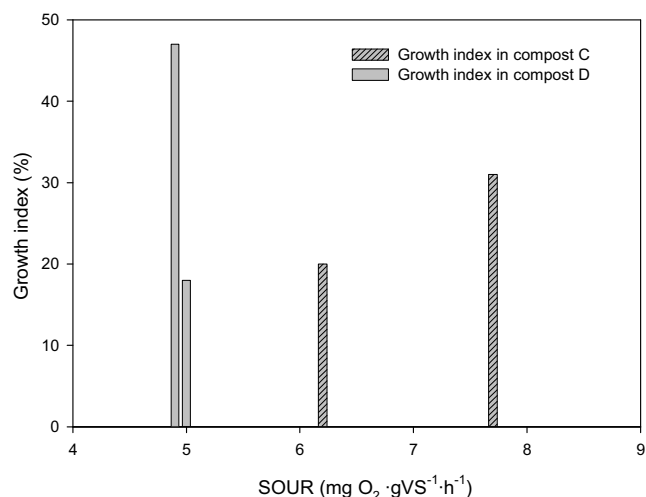


Fig. 8 Relationship between stability and maturity in compost C and D obtained using high-performance systems.

thod to determine *stability*, which is a much faster method, was only possible for the two composts produced in Spanish treatment plants in which OFMSW was processed. A significant mathematical relationship was found between GI and SOUR.

As regards the composts produced in Italy, in which the

OFMSW was mixed with a large amount of green trimmings, this correlation was not possible given that the SOUR method did not provide conclusive results concerning compost quality.

The aim of this study, to verify if the SOUR method can be considered a good indicator of compost *maturity* and predict its agronomic performance, depends on the nature of the material to be composted. Thus, further experiments with other types of compost must be conducted in the future.

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