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Diagnosis of the fertility of compost-based growing media: Method comparison and monitoring in pot plant cultivation

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ABSTRACT

Using compost instead of peat as an ingredient in substrate mixtures is a way of increasing the sustainability of pot plant nurseries. However, this use should also include monitoring to assess crop fertility, given that compost generally has a high fertilizer content. Of the different monitoring methods, the most effective, objective and preventive one involves monitoring the nutrient status of the substrate. The main objective of this study was to provide evidence-based information on fast methods used in the field to characterize substrate fertility compared to a water extract method in order to apply these methods in cultures with unusual alternative substrates.

We observed a high level of agreement between the concentration of nutrients measured using the IP method and the concentration using the fertility assessment methods most commonly used in horticulture (leachate and water extract methods). By using different compost-based substrates and comparing them to a control substrate, we have shown that the IP method is useful for monitoring substrate fertility in pot plants. Results show that the IP method indicates the nutrient composition of the functional part of the different substrates (root zone) and their development. The induced percolate method is a useful, nondestructive field method for quickly checking the nutrient content of the functional part of substrates.

1. Introduction

Using compost instead of peat as an ingredient in substrate mixtures is one of the measures proposed to increase the sustainability of nurseries that produce ornamental pot plants (Dennis et al., 2010). Because of the significant presence of the livestock industry in Western society, there is considerable interest in the potential of using composted manure solids as a substitute for peat (Shober et al., 2010; Al Naddaf et al., 2011). How its use affects crop fertilization and nutrient leaching must be closely studied (Bugbee, 1996; Marfà et al., 2002; Shober et al., 2010).

By regularly measuring substrate fertility, crop fertilization can be objectively assessed and supply can be adjusted (fertilizer type and mode) to optimize growth and minimize fertilizer loss, which can be quite significant (Yeager et al., 2010; Narváez et al., 2011, 2012, 2013). The induced percolate (IP) method (or pour-through method) is a procedure for obtaining a sample from the substrate solution by means of displacement (Yeager et al., 1983; Wright, 1986). It involves pouring about 100 mL of displacing solution (distilled water, irrigation water or NS) on the surface of the substrate and then collecting the resulting percolate from the bottom of the substrate. Through the piston effect, the displacing solution displaces the aqueous solution in closest contact with the roots so it can be collected (induced percolate) (Guérin et al., 1995; Lemaire et al., 1995). The advantages of this method include the ease and speed with which the sample is obtained and the fact that the method is nondestructive (Torres et al., 2010). In certain areas of the United States, nursery growers monitor substrate composition using the IP method and manuals are then used to assess substrate fertility (Yeager et al., 2010). The relationship between medium nutrient levels extracted with the IP and saturated media extract procedures (SME) has been investigated (Yeager et al., 1983; Wright et al., 1990; Cavins et al., 2004).

However, the SME method presents several practical drawbacks. It is time-consuming and difficult to precisely define the

Abbreviations: A-13®, perlite of particle size interval: 3–5 mm; B-12®, perlite of particle size interval: 0–5 mm; EC, electrical conductivity; EX, extract; IP, induced percolate; IRTA, Research and Technology, Food and Agriculture; LE, leachate; MCU, Multi Computer Unit; M-CS, mixture compost of solid fraction of cattle manure using static composting with B-12 perlite; M-CD, mixture compost of solid fraction of cattle manure slurry using dynamic composting with B-12 perlite; M-CDP, compost of solid fraction of cattle manure slurry with pine debris using dynamic composting with B-12 perlite; M-CON, peat with A-13 perlite; NS, nutrient solution; *R*, correlation coefficient; vol/vol, volume/volume.

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saturation state of the sample (Bunt, 1986; Ansorena, 1994). That is why water extract methods rather than the SME method are used to a great extent in Europe, and correlations between the English and Dutch methods have been established (substrate to water extract ratio of 1:6 and 1:1.5, respectively) (Ansorena, 1994).

The leachate method is being used to monitor the fertility of greenhouse soilless cultures where inorganic substrates are used. There are only few references on its use in the diagnosis of fertility in outdoor cultures when chemically active organic materials are used. The leachate method has not been correlated with other methods.

The bibliography does not include studies that validate the use of the IP method and establish possible correlations to methods widely used in Europe based on obtaining a water extract and leachates.

The main objective of this study was therefore to provide evidence-based information on fast methods used in the field to characterize substrate fertility compared to a water extract method, especially when using substrates that are alternatives to peat, given that substrate fertility must be carefully controlled in these cases due to its great variability. Several studies have analyzed the feasibility of replacing peat with compost-based substrates based on crop response, but the chemical composition of fertilizing ingredients is not generally monitored during growing using a nondestructive method that is easy to apply under field conditions.

Therefore, the main objectives of this study were:

- To gain greater insight into the relationship between nondestructive methods for monitoring substrate fertility in the field and the widely used water extract method (EX) based on a water/substrate volumetric ratio.
- To use the IP method to describe root-zone fertility during outdoor cultivation using high-fertility substrates.

Our general objectives were achieved with regard to the following topics:

- To study the correlation between the IP method of monitoring root-zone fertility and the water extract method, and to study the correlation between the nondestructive LE and IP methods.
- To describe the evolution of the fertility of mixtures of cattle-manure compost substrates during outdoor culture of container-grown bush species using the IP method.

2. Materials and methods

It is important to point out that this study of method comparisons was carried out:

- Under field conditions and using four different substrates, instead of using different doses of fertilizers. Therefore, the study was carried out under actual growing conditions.
- In particular, by conducting an experiment on an ornamental outdoor culture lasting six months and using a widely used species (oleander) that grew in up to four different organic substrates, including compost-based growing media.

2.1. Treatments: preparing mixtures of growing media

Three mixtures were prepared of different kinds of compost from the solid fraction of cattle slurry (CSF) and different proportions of perlite B-12® (0–5 mm) (Table 1). Sphagnum peat mixed with perlite A-13® (3–5 mm) (Hidalgo and Harkess, 2002; Shober et al., 2010) was used as the control substrate in a control treatment. The different proportions and kinds of perlite were used to create similar physical properties in all four substrates (Fig. 1) (Cáceres, 2003) (Table 1).

Table 1
Organic material and perlite mixtures used in the experiment.

Mixture	Organic material (OM)	OM (%) (vol/vol)	Perlite (PER)	PER (%) (vol/vol)
M-CS	CSF-S	75	B-12®	25
M-CD	CSF-D	45	B-12®	55
M-CDP	CSF-DP	30	B-12®	70
M-CON	PEAT	40	A-13®	60

CSF-S: compost of solid fraction of cattle manure slurry using static composting; screened (grid size = 10 mm).
CSF-D: compost of solid fraction of cattle manure slurry using dynamic composting; screened (grid size = 10 mm).
CSF-DP: compost of solid fraction of cattle manure slurry using dynamic composting with pine debris as a bulking agent; screened (grid size = 10 mm).
B-12®: perlite, particle size: 0–5 mm, A-13®: perlite, particle size: 3–5 mm.
OM: organic material; PER: perlite.

The organic components of the mixtures (CSF) were obtained at a composting pilot plant at the IRTA research center in Cabrils (Barcelona, Catalonia, Spain) (41°25′ N, 2°23′ E, altitude of 85 m). The types were as follows: CSF-S: compost of the solid fraction of cattle manure slurry using static composting; CSF-D: compost of the solid fraction of cattle manure slurry using dynamic composting; CSF-DP: compost of the solid fraction of cattle manure slurry using dynamic composting with pine debris as the bulking agent. The composting period lasted 14 months. The CSF-S compost had a high nitrate content because of its rate of high nitrification during composting (Cáceres et al., 2006) and it also presented a high K and P content (expressed in mg L^{-1} substrate) (NO_3^-: 1958, K^+: 1396; P: 111). The CSF-D compost presented a high nutrient content (NO_3^-: 843, K^+: 1587, P: 51) and the CSF-DP compost showed lower values (except for P) because of the dilution effect of the bulking agent (NO_3^-: 105, K^+: 1099, P: 57) (Cáceres, 2003) (Table 2).

2.2. Plant material and growing conditions

The experiment was carried out at an outdoor plot at the IRTA research station in Cabrils. Homogeneous rooted cuttings of oleander (*Nerium oleander* L.) were planted in 5-L pots placed at a distance of 40 cm from the other pots in all directions, thus resulting in a density of 6 plants m^{-2}.

A total of 24 plants were used for each treatment. An electrotensiometer was installed in one plant for each treatment; it activated the irrigation system when a matric potential of −2 kPa was reached. This threshold was chosen based on the physical

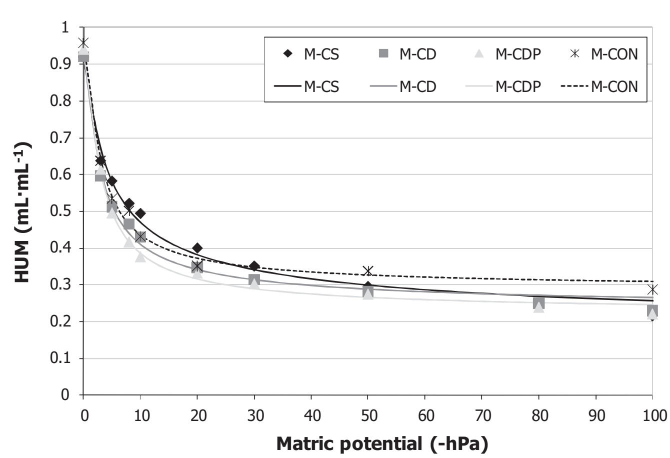

Fig. 1. Water retention curves of the four substrates used in the experiment (Cáceres, 2003).