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Evaluation of containerized substrates developed from cattle manure compost and synthetic aggregates for ornamental plant production as a peat alternative

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ABSTRACT

The aim of this research was to study the potential utilization of containerized substrates developed from cattle manure compost (CMC) and synthetic aggregates (SA) on the growth and nutrition composition of ornamental French marigold (*Tagetes patula*). Unconventional SA were produced from low productive acidic red soil with paper waste and starch waste. CMC was prepared from cattle manure and wood chips. Growth substrates were prepared by mixing CMC at the rates of 0%, 20%, 40%, 60% and 100% with SA at 100%, 80%, 60%, 40% and 0%, respectively. Peat only was used as the control. The physical and chemical characteristics of all containerized substrates were analyzed. CMC–SA based substrates showed adequate physical and chemical properties compared to peat for their use as containerized substrates in horticulture. In relation to the plant growth in peat control, plants grown in the CMC–SA based substrates reached better growth and nutrition. The highest plant height, number of flowers per plant, shoot fresh weight, shoot dry weight, root length, root fresh weight and root dry weight obtained from the mixture of CMC and SA at 40% and 60% treatment were increased by 27.01%, 42.86%, 37.09%, 67.29%, 5.14%, 45.58% and 34.26%, respectively compared to peat control. The concentration of trace elements in plant tissues was far lower than the ranges considered phytotoxic for plants. Utilization of CMC and SA can be considered as alternative substrates to substitute the widely using expensive peat in horticulture.

1. Introduction

Increasing demand and rising costs for peat as a growing substrate in horticulture have led to search for high quality and low cost substrates as an alternative (Chong, 2005; Wilson et al., 2006; Ostos et al., 2008; Gil et al., 2008a,b; Moral et al., 2009). A number of studies have shown that organic residues such as urban solid wastes, sewage sludge, animal manure and dung, paper waste, pruning waste, spent mushroom and even green wastes, after proper composting, can be used with very good results as container growth substrates instead of peat (Zaller, 2007; Ostos et al., 2008; Bustamante et al., 2008; Moral et al., 2009; Wright et al., 2008; Miaomiao et al., 2009; Tumuhairwe et al., 2009). The increasing interest in waste recycling is another cause to advocate the recycling and use of organic wastes and composts as soil or potting amendments; it could be one of the most attractive methods of solving the problem of waste disposal (Banegas et al., 2007; Kanat et al., 2006; Liu et al., 2009). The combination of peat and compost in a growing substrate is synergistic; peat often enhances aeration and water retention and compost improves the fertilizing capacity of a substrate (Zaller, 2007). In addition, organic by-products and composts tend to have porosity and aeration properties comparable to those bark and peat and as such are ideal substitutes in propagating substrates (Chong, 2005). Moreover, composts tend to improve the organic matter content of the substrates (Qazi et al., 2009).

In recent years, the intensive and industrial livestock production system has resulted in high density of animals in relatively small areas and producing large quantities of manure (Ko et al., 2008; Gil et al., 2008a). Thus, livestock production has become separated from its land base and has difficulty in treating the manures within internal management (Richard and Choi, 1999). This has led to environmental problems for people, including water contamination (Elwell et al., 2001; Gay et al., 2003; Gil et al., 2008a; Ko et al., 2008; Giusti, 2009). Therefore, the need for more environmentally friendly methods for the treatment and utilization of animal manure has become imperative. There are several kinds of animal waste treatment methods, such as composting, lagoon, evaporation, and water purification. Composting cattle manure produces a stabilized product that leads to the development of microbial populations, which causes numerous physico-chemical changes in the waste mixture (Cai et al., 2007) and improves the handling

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characteristics of manure by reducing volume and weight (Eghball and Power, 1999; Adamtey et al., 2009). Cattle manure compost (CMC) are considered as a valuable product that can be used as a source of soil amendment and organic matter in agriculture which improves the quality of the crop and the environment (Hoitink, 2000; Ko et al., 2008). CMC did not cause any heavy metal pollution and there were no phytotoxicity symptoms found in maize plants treated with CMC (Gil et al., 2008a). Composts may have physical, physico-chemical and chemical properties similar to peat that make them suitable as peat substitutes (Sanchez-Monedero et al., 2004). Moreover, CMC addition to soil improve the soil quality, soil organic matter, soil aggregate stability, water holding capacity, water infiltration, hydraulic conductivity and nutrient content (specially N, P and K) (Sager, 2007; Barrtl et al., 2002; Castrillion et al., 2009; Indraratne et al., 2009). However, the combination of peat with composts can reduce the potential poor properties of single materials, such as high salinity, heterogeneity or high content of contaminants (Raviv et al., 1986).

Widely spread red soil ("Kunigami Mahji") in sub-tropical Okinawa, Japan, which is classified as an ultisol, is not suitable for crop production due to its poor physical (Tokashiki et al., 1994) and chemical properties (Hamazaki, 1979; Onaga and Yoshinaga, 1988). This prompted for the development of an effective method of converting under utilized red soil into fertile, arable SA by incorporating paper waste and starch waste in order to improve its physical and chemical properties. The starch waste coming out as a waste material from Okinawa Seifun Corporation Okinawa, Japan was used as the SA binder as described in our previous studies (Jayasinghe et al., 2005, 2008, 2009). Moreover, SA developed from coal fly ash with paper waste and acidic red soil was utilized as plant growth substrate in our previous studies (Jayasinghe et al., 2007, 2008, 2010). The ornamental plant production industry is one of the fastest growing major segment of Japan agriculture, accounted for 13% from the global production, has a production value of 3147 million Euros per annum (Wijnands, 2005). The total area for ornamental plant production in Japan in 2004 was 22,382 ha, out of which 51% was from protected houses (Wijnands, 2005). During last two decades due to improved popularity for protected agriculture, evolution of plant growth techniques has increased demand for container substrates such as peat, zeolite, and perlite, but the supply have been decreasing (Inbar et al., 1990). Depletion of non-renewable resources and environmental deterioration together with high prices of those substrates have favored the utilization of alternative materials as growth substrates (Abad et al., 2001). In this study CMC along with SA were used to improve the properties of the growth substrates for crop production. The aims of the present work were: (1) to evaluate the main physical and chemical properties of the containerized substrates developed from CMC and SA, and (2) to ascertain the potential utilization of these CMC–SA based substrates as an alternative to widely using peat substrates for ornamental French marigold cultivation by studying their effects on vegetative and nutritional aspects to determine if there is any limitation to their use.

2. Materials and methods

2.1. Collection of samples

CMC was collected from a local industrial composter (Takathomi Bussan, Pvt. Ltd., Kagoshima, Japan). The compost was produced from cattle manure and wood chips. Compost was fully matured (compost which underwent adequate decomposition). Red soil samples were collected from Miyagi-Sajibaru, Higashi-Son, Kunigami-Gun, Okinawa, Japan. The soil texture used to produce SA was clay and is classified as an Ultisol. Collected soil samples were air-dried and then sieved through a 10-mm mesh screen and utilized for SA production. A portion of this soil sample was sieved through a 2-mm mesh sieve, and used for chemical analysis. Paper waste was collected from Ojiryokka Company, Tokyo, Japan. Starch waste and peat samples were obtained from Okinawa Seifun, Corporation Ltd., Okinawa, Japan. Physical and chemical properties of the paper waste and soil are given in Table 1.

Table 1
Selected physical and chemical properties of paper waste and red soil used in the experiment.

Particulars	Paper waste	Red soil
Bulk density ($g\,cm^{-3}$)	–	1.26 ± 0.03
Particle density ($g\,cm^{-3}$)	–	2.65 ± 0.06
pH	5.70 ± 0.32	4.96 ± 0.14
EC ($dS\,m^{-1}$)	0.10 ± 0.001	0.04 ± 0.001
C ($g\,kg^{-1}$)	374.8 ± 2.76	1.73 ± 0.04
N ($g\,kg^{-1}$)	0.38 ± 0.10	0.40 ± 0.04
P ($g\,kg^{-1}$)	0.06 ± 0.01	0.03 ± 0.01
Na ($g\,kg^{-1}$)	0.24 ± 0.09	0.06 ± 0.01
K ($g\,kg^{-1}$)	0.32 ± 0.05	0.05 ± 0.01
Mg ($g\,kg^{-1}$)	0.47 ± 0.11	0.02 ± 0.00
Ca ($g\,kg^{-1}$)	0.63 ± 0.17	0.07 ± 0.01
As ($mg\,kg^{-1}$)	ND	ND
Cr ($mg\,kg^{-1}$)	3.70 ± 0.34	1.20 ± 0.10
Cu ($mg\,kg^{-1}$)	8.50 ± 0.49	13.81 ± 0.22
Se ($mg\,kg^{-1}$)	ND	ND
Mn ($mg\,kg^{-1}$)	6.52 ± 1.26	20.65 ± 1.95
Cd ($mg\,kg^{-1}$)	ND	ND
Zn ($mg\,kg^{-1}$)	10.10 ± 0.42	27.31 ± 2.98
Pb ($mg\,kg^{-1}$)	0.63 ± 0.16	4.70 ± 0.06

EC: electrical conductivity, ND: not detected; values are mean ± standard deviation (n = 5).

2.2. Production of synthetic soil aggregates (SA)

SA were produced by combining red soil and paper waste using an Eirich mixer (R-02M/C27121) with starch waste as a binder according to Jayasinghe et al. (2005, 2008, 2009, 2010). 1000 g of red soil, 100 g of waste paper and 25 g of lime were mixed in Eirich mixer by adding 225 ml of starch paste (starch paste was produced adding 25 g of starch to 200 ml hot water) for the production of SA.

2.3. CMC and SA mixtures utilized under the study

Table 2 shows volumetric formulations of different SA and CMC mixtures used in the study.

2.4. Analytical methods

The pH was measured in water extracts of all substrate samples using a glass electrode (sample: distilled water ratio of 1:5), and electrical conductivity (EC) was measured using an EC meter (D-54, Horiba) (sample: distilled water ratio of 1:5). Carbon (C) and nitrogen (N) contents in substrate samples were determined by using CN analyzer (Micro coder JM 10; G-Science Laboratory, Tokyo, Japan). Organic matter (OM) contents of the substrate samples were determined by loss on ignition at 430 °C for 24 h (Navarro et al., 1993).

Table 2
Composition of containerized media used in the experiment.

Media	Formulation
T1	Peat only (commercial media)
T2	SA only
T3	CMC20%:SA 80% (v/v)
T4	CMC 40%:SA 60% (v/v)
T5	CMC 60%:SA 40% (v/v)
T6	CMC only

SA: synthetic aggregates, CMC: cattle manure compost, v/v: volume basis.