Physical Properties of Peat-based Substrates Amended with a Mature Dairy Cow Manure Compost Before and After Plant Cultivation[1]

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Abstract

Initial and final physical properties of four substrates based on a sphagnum peat moss:perlite (3:1 v/v) substrate where mature dairy manure compost (DMC) was partially substituted for peat moss at 0, 16, 26, or 33% DMC of total substrate volume (equivalent to DMC to peat moss ratios of 0, 1, 2, or 3 on a dry weight basis, respectively) were evaluated during a 12-week crop of 'Macumba' pot chrysanthemum [*Dendranthema* × *grandiflora* (Ramat.) Kitam]. The impact of time on physical properties was similar in all substrates, indicating that DMC was as stable as peat moss. Addition of DMC to substrates increased bulk density (D_b) and lowered total porosity (TP) and air space (AS). Compared to peat moss plus perlite without DMC, container capacity (CC) increased with 16 and 26% DMC and was similar at 33% DMC. Addition of DMC at 33% resulted in a decrease in available water (AW). Plant shoot dry weight was higher in all substrates containing DMC, with the maximum at 26% DMC, compared to peat moss plus perlite without DMC.

Index words: chrysanthemum, *Dendranthema* × *grandiflora*, bulk density, container capacity, air space, porosity, available water.

Species used in this study: chrysanthemum [*Dendranthema* × *grandiflora* (Ramat.) Kitam 'Macumba'].

Significance to the Horticulture Industry

There is a strong desire in the horticulture industry today to find soilless root substrate components that utilize local resources to reduce production costs. Composted materials are prime candidates for this role. Dairy manure is of particular interest because it lends itself well to thorough composting. Mature DMC is an excellent root substrate component because it is relatively free of volume shrinkage during cropping, most ammoniacal nitrogen has been converted to nitrate, which prevents ammonium toxicity, and it does not lower substrate pH, but instead, stabilizes it. This study demonstrated that DMC had comparable shrinkage during a 12-week chrysanthemum crop as sphagnum peat moss, a component valued for its stability. Shifts in physical properties resulting from the inclusion of DMC into a substrate were not detrimental to chrysanthemum growth. When DMC was added in a 3 peat moss:1 perlite substrate, plant growth improved with the maximum response at 26% DMC. Thus, DMC can be a viable, partial substitute for peat moss in the soilless substrate used in greenhouses and container nurseries.

Introduction

Most greenhouse plants are grown in soilless media, primarily consisting of organic materials such as sphagnum peat moss, pine bark, and sometimes compost. When compost materials are used as one of the components in container substrates, reduction in substrate bulk volume (shrinkage) over time due to the possible microbial decomposition of organic materials during crop production has been a concern (Chen et al. 2002, Nash and Pokorny 1990). The physical properties of a root substrate can indicate the extent of gas exchange and availability of water in the rhizosphere for plant roots, which are significant factors determining plant growth and quality. A high capacity for moisture retention and drainage of excess water are important physical properties of a root substrate (Corti et al. 1998). Water retention at container capacity significantly decreased with increasing proportions of composted yard trimmings in peat-pine bark-based container substrate (Chen et al. 2002).

Use of DMC has contributed to sustainable agricultural production by utilizing animal waste to improve soil quality (Butler et al. 2008, Butler and Muir 2006, Eghball 1999, Klausner et al. 1998). Dairy manure compost and other composted materials, such as fiber from digested cattle slurry or composted cattle slurry fiber, have been used as a substitute for peat moss in root substrates for a number of crops (Bradley et al. 1996, Chen et al. 1986, Prasad 2008). When DMC is composted to the point of maturity where most of the ammoniacal nitrogen has been converted to nitrate and the release of carbon dioxide has subsided to a low level, problems such as ammonium toxicity, pH suppression, and substrate volume shrinkage are avoided. Jeong et al. (2011) reported additional benefits from mature DMC are its liming effect and high substrate pH buffering capacity. Mature compost has subsided in heating (Weppen 2002), has reduced CO_2 respiration and has little or no presence of free ammonia (NH_3) (Changa et al. 2003). There is limited information concerning the impact of mature DMC on physical properties in container root substrates over time. The objectives of this study were 1) to quantify the impact of adding mature DMC on physical properties of peat-based substrates and 2) to test changes in physical properties of the substrates containing DMC between the beginning and end of a crop cultivation period.

Materials and Methods

The DMC was prepared by Woods End Laboratories, Inc., Mt Vernon, ME, from dairy cow manure plus spoiled-silage

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using the turned-pile method. The combined components of the compost feedstock were obtained from a local dairy farm that produces both milk and compost. The primary carbon source for the compost was hardwood sawdust bedding which was contained in the cow manure. Spoiled silage, a normal waste product from dairy farm operations, comprised up to 20% of the initial compost volume. Uncomposted manure on its own tends to be very dense and have a very low C:N ratio. Typical densities for uncomposted manure, silage, and sawdust are 836 kg·m^{-3} (1,400 lb·yd^{-3}), 239 to 477 kg·m^{-3} (400 to 800 lb·yd^{-3}), and 179 to 239 kg·m^{-3} (300 to 400 lb·yd^{-3}), respectively. Typical C:N ratios for uncomposted manure, silage, and sawdust are 10:1, 20:1, and 100:1, respectively (W. Brinton, Woods End Research Laboratory, Mount Vernon, ME, personal observations). The farmer controlled the amount of carbon in the compost feedstock by adjusting the time of manure removal from the barn and adding silage to achieve a density of 656 kg·m^{-3} (1,100 lb·yd^{-3}) and C:N ratio of 30:1. The use of spoiled silage in the DMC is justified by the following benefits: 1) converting a waste product into a resource, 2) adding a high N material to further enhance composting, and 3) increasing aeration through lower density and improved porosity during composting. It is assumed that silage has little effect on the final properties of the compost because its C:N ratio and density are intermediate between manure and sawdust and silage is the main raw ingredient in generating manure.

The 4.3 m (14 ft) diameter by 1.8 m (6 ft) high conical-shaped compost pile was turned five times during the first 90 d by lifting and mixing with a tractor-mounted, front-end loader. Within seven days, the core temperature of the pile rose to 57 to 60 C (135 to 140 F) and remained at 49 to 57 C (120 to 135 F) for six weeks. After the DMC cooled below 30 C (86 F), the pile was stored outdoors for 60 d by covering with ComposTex® compost fabric [Texel, a Division of ADS Inc., Saint-Elzéar-de-Beauce, Québec, Canada], a polypropylene spun fabric permeable to oxygen, carbon dioxide, and water vapor but sheds precipitation.

To ascertain stability and maturity during compost production, the C:N ratio was analyzed and a Solvita® Compost Maturity test kit (Woods End Laboratories, Inc., Mt. Vernon, ME) was used to measure CO_2 respiration and free NH_3 (Changa et al. 2003, Wang et al. 2004). Following storage, the C:N ratio, CO_2 respiration index and free NH_3 index were 16.4, 7.58, and 4.72, respectively, indicating a high level of maturity. Prior to analysis and use, the DMC was sieved through a 13-mm screen and mixed in a Twister™ II Batch Mixer, (Bouldin & Lawson, McMinnville, TN). Compost samples were analyzed by the North Carolina Department of Agriculture and Consumer Services Waste Analysis Lab in Raleigh, NC. The macronutrient concentrations on a percent dry weight basis were: 1.77 N, 0.42 P, 0.76 K, 1.80 Ca, 0.56 Mg, and 0.23 S. The micronutrient concentrations on a dry weight basis in mg·kg^{-1} (ppm) were: 3,486 Fe, 352 Mn, 135 Zn, 758 Cu, and 25 B. The cation exchange capacity was 36.7 meq·100 cm^{-3} as determined by a summation of cations. Base saturation was 100%. The pH measured 8.0 in a 2:1 deionized water filtrate. The electrical conductivity (EC) was 5.1 mS·cm^{-1} by the saturated paste method. The C:N ratio was 13.3 and calcium carbonate equivalence was 1.67% (dry weight basis).

Four root substrates were prepared using 75% organic material (DMC and/or sphagnum peat moss) and 25% perlite on a v/v basis. The four substrates contained 0, 16, 26, and 33% of the total volume as DMC, with the remainder of the organic material composed of peat moss. The 0, 16, 26, and 33% DMC was equivalent to a DMC to peat moss ratio of 0:1, 1:1, 2:1, and 3:1, respectively, on a dry weight basis. Each substrate was adjusted to pH 6.5 by incorporating agricultural dolomitic limestone at 180, 240, 140, and 40 g·kg^{-1} (2.88, 3.84, 2.24, and 0.64 oz·lb^{-1}, respectively) dry peat moss for 0, 16, 26, and 33% DMC, respectively. All treatments also included AquaGro 2000 G (Aquatrols, Paulsboro, NJ) wetting agent at the label rate of 0.6 g·dm^{-3} (1 lb·yd^{-3}) of substrate.

To facilitate physical properties tests, the plant culture container used in this experiment consisted of a cylinder with an inside diameter (i.d.) of 7.6 cm (3 in), a height of 15.2 cm (6 in), and a volume of 344 cm^3 (20.99 in^3). The cylinders for the initial substrate tests (I-cylinder) consisted from the bottom up of a 2.5 cm (1 in) tall PVC ring, a 7.6 cm (3 in) tall aluminum core to be used in the NCSU porometer test, and a 5.1 cm (2 in) tall PVC ring. The three parts were taped together with duct tape. Cylinders for final substrate tests at week 12 (F-cylinder) consisted of a 7.6 cm (3 in) i.d. by 15.2 cm (6 in) tall PVC ring. All PVC rings were cut from 3 in i.d., schedule-40 PVC pipe. A 3.2 mm (0.125 in) wide by 1.6 mm (0.0625) in deep groove was cut 12.7 mm (0.5 in) from bottom of the lowermost section of each cylinder using a wood lathe. A 15.2 cm (6 in) × 15.2 cm (6 in) square piece of fiberglass window screen was used to cover the base. The screen was then secured to the cylinder by tying a 33 cm (13 in) long piece of 14-gauge insulated solid copper electrical wire at the groove. Twenty-three cylinders (ten I-cylinders and thirteen F-cylinders) for each of the four substrates were then fully-filled with substrate and compacted by dropping each cylinder 3 times from a height of 15.2 cm (6 in).

After the third irrigation (one week after initiation) with tap water, the aluminum core containing the substrate within each I-cylinder was recovered by removing the duct tape and cutting the substrate above and below the aluminum core with a serrated knife. Once the upper and lower rings were removed and discarded, the ten I-cylinder cores were ready for the physical properties tests.

One rooted cutting of the pot chrysanthemum 'Macumba' was transplanted into each F-cylinder on January 11. The plants were grown for 12 weeks in a glass greenhouse at 35°N latitude in Raleigh, NC. Day and night temperatures were set at 24 and 18 C (75 and 65 F), respectively. A water soluble fertilizer, 17N-2.2P-14.1K (Greencare 17N-5P_2O_5-17K_2O, Kankakee, IL) with a potential acidity/basicity rating of zero (calcium carbonate equivalent) was used in this study. The fertilizer solution was formulated in deionized water and applied at a concentration of 200 mg·L^{-1} N to the top of the substrate at each irrigation with approximately 20% leaching. The frequency of irrigation ranged from twice weekly at the beginning to daily at the end of the experiment. Incandescence light was applied at an intensity of 2 μmol·m^{-2}·s^{-1} for the first two weeks from 10:00 PM until 2:00 AM daily to retard floral initiation. The natural short-day photoperiod was utilized thereafter to promote flowering.

At the end of crop cultivation, plants were harvested at the substrate surface level and dried in a forced draft oven at 70 C (158 F) for 48 h to constant weight for determination of shoot dry weight. After harvesting a plant from each F-cylinder, the screen was removed from the base of the column. The substrate column was pushed out of the cylinder into a 7.6 cm (3 in) i.d. by 7.6 cm (3 in) tall aluminum core. The substrate core was positioned in the aluminum core with 2.5 cm (1 in) protruding from the bottom. The bottom 2.5 cm (1 in) and the top portion of substrate were separated with a serrated knife and discarded to prepare the aluminum core for the physical property and particle size distribution tests. In this way, the substrate was sampled from the I- and F-cylinders for the porometer, 300-cm tension, and particle size distribution tests were obtained from the same substrate zone [2.5 to 10.1 cm (1 to 4 in) from the bottom of the cylinders].

Physical properties. Five of both the I-cylinders and F-cylinders for each DMC level were evaluated in the NCSU porometer test for dry bulk density (D_b), total porosity (TP), container capacity (CC), and air space (AS) at CC (Fonteno, 1996). Five additional cylinders of both types for each DMC level were placed in Buchner funnels with saturated porous plates having an air entry pressure >40 kPa (Milks et al. 1989). Following two days of slow saturation of the substrate, determination of retained volumetric moisture was measured at pressures of 0, 0.4, 1, 2, 4, 5, 7.5, 10, 20, and 30 kPa using Karlovich and Fonteno's (1986) adaptation of the Fonteno et al. (1981) procedure. Available water (AW) was determined by calculating the water collected between 0.4 and 30 kPa. Moisture release data from the ten pressure points were used in the equilibrium capacity variable model presented by Milks et al (1989) that combines the nonlinear moisture retention function of Van Genuchten and Nielsen (1985) with container geometry to predict CC, AS and AW for several container-substrate combinations.

Particle size distribution (PSD). Extra substrate from each treatment was used to determine the initial PSD. Roots were removed from the three remaining F-cylinders and used for the final PSD. All substrate samples were dried at 105 C (221 F) until each reached a constant weight. Three 100 g samples of each substrate-sampling time (initial and final) combination were sieved for 5 min in a Ro-Tap Testing Sieve Shaker Model B (Tyler Industrial Products, Mentor, OH) using 6.3, 2.0, 0.71, 0.50, 0.25, and 0.106 mm screens (3.2, 10, 25, 35, 60, and 140 mesh sizes, respectively). The separated particles were pooled and weighed into three categories: large (>2.00 mm), medium (2.00 to 0.50 mm) and fine (<0.50 mm).

Physical properties simulations. The initial CC, AS, and AW physical properties of the 0 and 26% DMC substrates for a range of container types and sizes commonly used in the greenhouse and nursery industries were calculated using the equilibrium capacity variable model from Milks et al. (1989). These simulations were based on the data collected using the 344 cm^3 (3 in) aluminum core. The dimensions used for the 1.67 cm^3 cell (800 plug) were 1.10 cm (0.43) top-width (t-w) by 0.90 cm (0.35 in) bottom-width (b-w) by 2.80 cm (1.10 in) depth (dpt). Equivalent measurements for the 4.50 cm^3 cell (273 plug), 25.30 cm^3 cell (128 plug), and 88.37 cm^3 cell (48 cell bedding plant flat) were 1.65 cm (0.65 in) t-w by 1.00 cm (0.39 in) b-w by 2.50 cm (0.98 in) dpt, 2.80 cm (1.10 in) t-w by 1.65 cm (0.65 in) b-w by 5.00 cm (1.97 in) dpt, and 5.00 cm (1.97 in) t-w by 3.30 cm (1.30 in) b-w by 9.00 cm (3.54 in) dpt, respectively. Pot sizes included in the simulations were 600 cm^3 (4 in standard), 1,930 cm^3 (6 in standard), and 3,785 cm^3 (#1 nursery). The container sizes of 1.67, 4.50, 25.30, 88.37, 600, 1930, and 3,785 cm^3 were equivalent to 0.10 in^3, 0.27 in^3, 1.54 in^3, 5.39 in^3, 20.99 in^3 (0.73 pt), 36.61 in^3 (0.63 qt), 117.78 in^3 (0.51 gal), and 230.97 in^3 (1 gal), respectively.

Experimental design and statistical analysis. A two-way factorial arrangement of two sampling times (initial and final) and four DMC contents (0, 16, 26, and 33% DMC by volume) in a randomized complete block design with five blocks (40 experimental units in total) was employed for the physical properties determination. There were four DMC content levels arranged in a randomized complete block with five blocks for plant growth (20 experimental units). A two-way factorial arrangement of two sampling times (initial and final) and four DMC contents (0, 16, 26, and 33% DMC by volume) in a randomized complete block design with three blocks (24 experimental units in total) was employed for the particle size distribution. Each cylinder was an experiment unit. All data were subjected to analysis of variance using the PROC ANOVA procedure of SAS 9.3 (Statistical Analysis System, SAS Institute, Cary, NC). Data values for dependent variables with significant analysis of variances were regressed by sampling time using the PROC GLM procedure to determine the best-fit linear and quadratic models. Data values for physical properties were pooled into a single regression model because of a non-significant test for sampling time by DMC content interaction. Data values for growth were also in a single regression model because there was only one sampling time. Terms of the model were based on a comparison of F-values at $\alpha = 0.05$.

Results and Discussions

Significant differences in D_b did not occur as a result of sampling time or sampling time by DMC content, indicating that D_b was stable throughout the 12 week crop cycle (data not shown). However, there was an increasing quadratic response of D_b (pooled over time) as DMC content increased (Fig. 1A). The D_b of 0% DMC was 0.08 $g \cdot mL^{-1}$, which was lower than that of the other three substrates due to the much higher D_b of DMC (0.31 $g \cdot mL^{-1}$) compared to peat moss D_b (0.07 $g \cdot mL^{-1}$). However, increasing the percentage of DMC from 16 to 33% had little effect on D_b, which were 0.15, 0.14, and 0.15 $g \cdot mL^{-1}$ for 16, 26, and 33% DMC, respectively. Since the initial and final D_b were similar for each substrate treatments, one can infer there were no significant effects from factors such as irrigation, plant growth, or decomposition of organic materials during crop production.

No significant differences occurred between the two sampling times nor a sampling time by DMC content level interaction for TP. This indicated that TP was maintained throughout the 12-week crop. There was a decreasing linear response of TP (pooled over time) with increasing DMC content in the substrate (Fig. 1B). Total porosity was lower at 26 and 33% DMC than at 0 and 16% DMC. However, the lowest TP (86.8%) in our study was still higher than the TP (77 to 78%) reported by Bugbee (2002) in a 25 to 100% substitution of composted municipal biosolids for a softwood bark:peat:sand (3:1:1, by vol) substrate. Although the TP was reduced to 77% with 50% biosolids from 85% with 0% biosolids, Bugbee reported greater plant growth in the substrates with the compost. This suggests that the TP for 26 and 33% DMC observed in our trial were still within an optimal range.

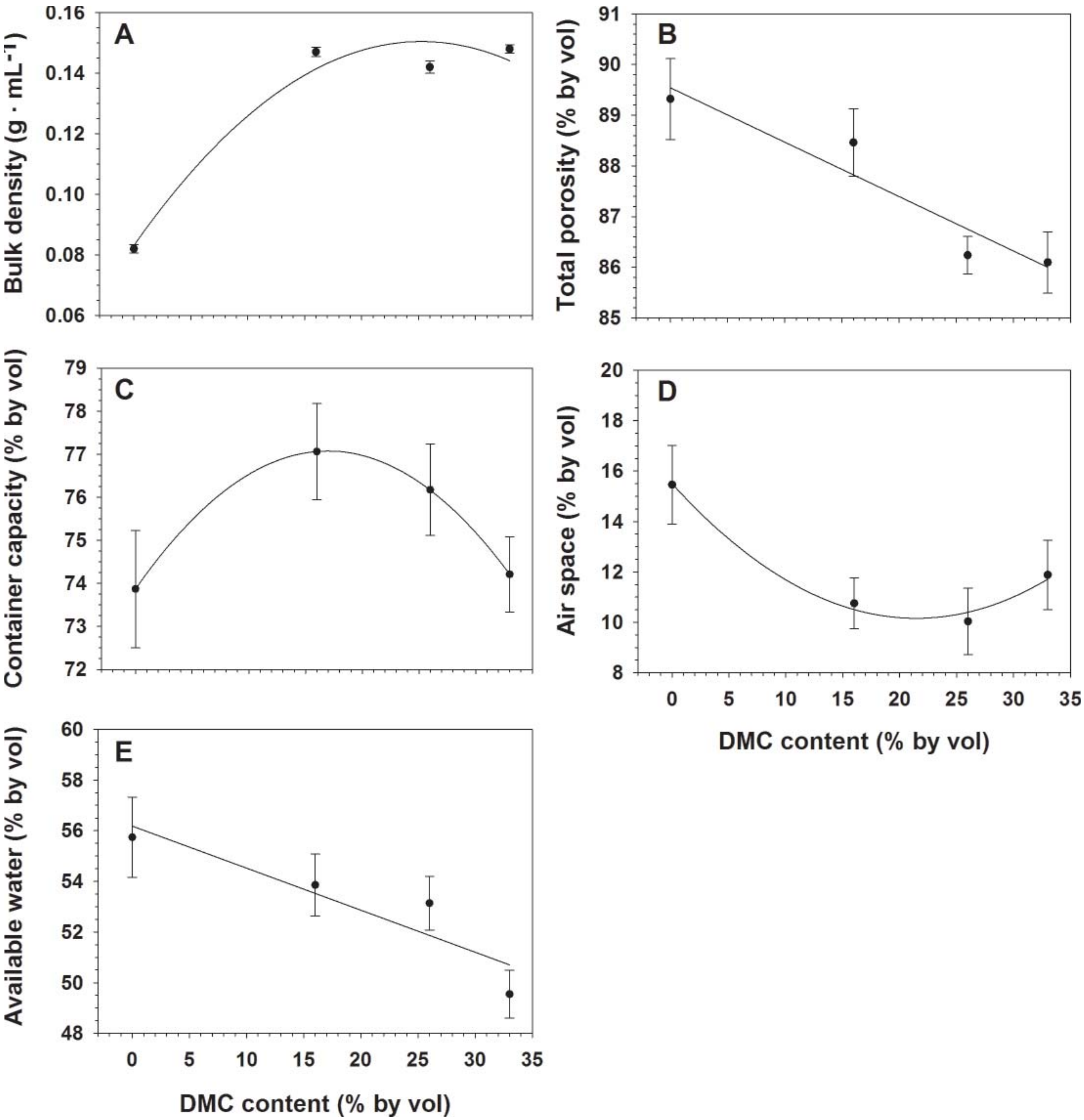

Fig. 1. Effect of dairy manure compost (DMC) used as a partial substitute for sphagnum peat moss in a 3 sphagnum peat moss:1 perlite container substrate (v/v) and sampling time on the mean A) dry bulk density (D_b), B) total porosity (TP), C) container capacity (CC), D) air space (AS), and E) available water (AW) in a 7.6 cm tall column at the beginning (initial) and the end (final) of chrysanthemum 'Macumba' cultivation. Data for the two sampling times were pooled, because the effects of sampling time × DMC content interactions were not significant. The regression equations generated for the best fit models were: A) $y_{Db} = -0.0001055x^2 + 0.005331x + 0.08311$ ($r^2 = 0.93$), B) $y_{TP} = -0.1073x + 89.54$ ($r^2 = 0.33$), C) $y_{CC} = -0.01304x^2 + 0.4362x + 73.90$ ($r^2 = 0.18$), D) $y_{AS} = 0.01162x^2 - 0.4982x + 15.50$ ($r^2 = 0.21$), and E) $y_{AW} = -0.1659x + 56.18$ ($r^2 = 0.23$). Bars indicate ± S.E. (n = 10).

There were significant differences in CC due to sampling time and DMC content, but there was no interaction. The mean initial and final CC, pooled over DMC content, were 72.6 and 78.4%, respectively, indicating an increase in CC during crop production. When pooled over time, there was a quadratic effect of DMC content on CC (Fig.1C). The partial substitution of DMC for peat moss increased the mean CC from 73.9% in the 0% DMC substrate to 77.7% in the 16% DMC substrate. The CC at higher levels of DMC were similar to the 0% DMC.

There were significant differences in AS due to sampling time and DMC content, but there was no interaction. The mean initial and final AS, pooled over DMC contents, were 15.3 and 8.8%, respectively, indicating a decrease during crop production (data not shown). There was a quadratic response with mean AS, pooled over time, decreasing with increasing DMC addition (Fig.1D). The partial substitution of DMC for peat moss decreased the mean AS of 15.4% in the 0% DMC to 10.7, 10.0, and 11.9% in the 16, 26, and 33% DMC substrates, respectively. However, AS in the three substrates containing DMC were not statistically different.

There were significant differences in AW due to sampling time and DMC content, but there was no interaction. The mean initial and final AW, pooled over DMC content, were 49.8 and 56.3%, respectively, indicating an increase during crop production (data not shown). There was a negative linear response with mean AW, pooled over time, decreasing with increasing DMC content in the substrate (Fig. 1E). Available water was greater in the 0% DMC substrate (55.7%) than in the other three substrates; 16, 26, and 33% DMC had 53.8, 53.1, and 49.5% AW, respectively.

Changes in CC, AS, and AW observed in the four substrates during cultivation was likely due in part to plant root growth in the container since these changes also occurred in the 0% DMC treatment, which was a very physically stable substrate. Roots can be expected to partially fill pore space, thereby reducing AS. Also, the root system increases surface area for holding water, which results in increased CC at the further expense of AS. There were no differences observed in the percentage of large particles (>2.00 mm) due to sampling time, substrate composition or the interactions of these independent variables (data not shown). The mean percentage of large particles in all treatment combinations was 30.5%. There were effects of DMC content and sampling time by DMC content interactions on the percentage of medium particles. There was a positive linear response with the mean percentage of medium particles (2.00 to 0.50 mm) increasing with increasing levels of DMC at the initial sampling time (Fig 2A). The smallest percentage of medium particles were in the 0% DMC substrate (38.8%), an intermediate percentage at 16 and 26% DMC (44.3 and 42.4, respectively), and the largest percentage at 33% DMC (47.7%). Both the linear and quadratic regression models for the percentage of medium particles at the final sampling time were not significant, indicating that there were no differences between the four levels of DMC. The mean percentage of medium particles in all four substrates at the final sampling time was 44.3%. There were significant effects of sampling time and sampling time by DMC content interactions on the percentage of fine particles (<0.50 mm) at the initial sampling time. There was a negative linear response with the mean percentage of fine particles decreasing with increasing levels of DMC at the initial sampling time (Fig. 2B). The 0% DMC substrate had a greater percentage of fine particles (29.8%) than the 16, 26, and 33% DMC substrates with 26.2, 25.8, and 24.5%, respectively. However, at the final sampling time, there was a quadratic response with the lowest percentage of fine particles in the 0% DMC (21.9%) as compared to 25.5, 27.8, and 24.1% in the 16, 26, and 33% DMC substrates, respectively. Overall, DMC addition resulted initially in enrichment of the substrate with medium size particles at the expense of fine particles. This shift toward larger particle sizes is a desirable feature, particularly in shallower plug and bedding plant containers, where water retention is high, resulting in lower aeration and higher D_b. The shift toward

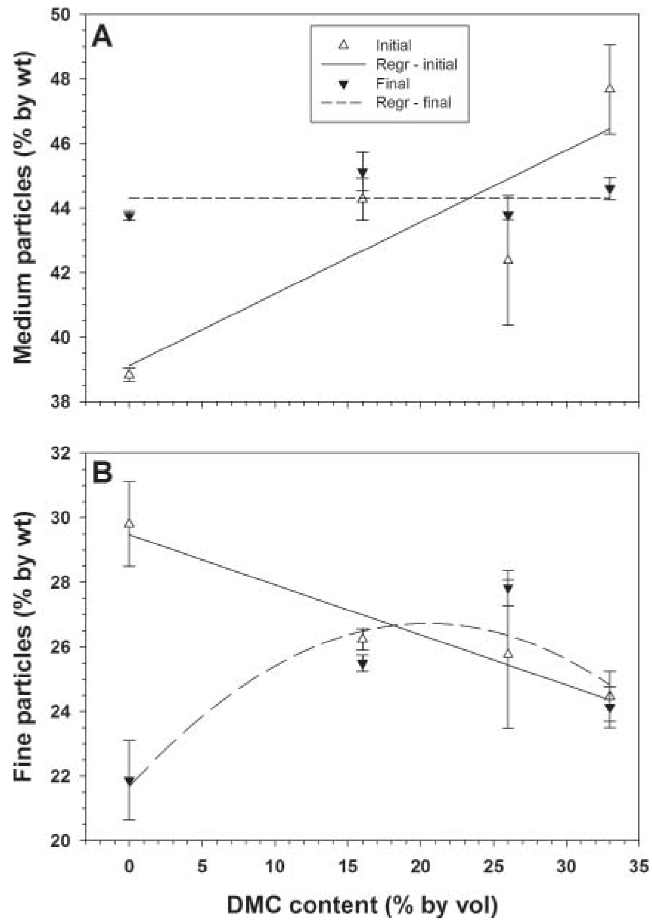

Fig. 2. Effect of dairy manure compost (DMC) used as a substitute for sphagnum peat moss in a 3 sphagnum peat moss:1 perlite container substrate (v/v) on the percentage of A) medium and B) fine particles in the substrate at the beginning (initial) and the end (final) of chrysanthemum 'Macumba' cultivation in a 7.6 cm tall column. The result of the regression (Regr) analysis for medium-sized particles on the final sampling date was nonsignificant. The regression equations generated for the best fit models were: A) $y_{initial\ medium} = 0.2221x + 39.12$ ($r^2 = 0.56$) and $y_{final\ medium} = 44.3$ and B) $y_{initial\ fine} = -0.1552x + 29.48$ ($r^2 = 0.48$) and $y_{final\ fine} = -0.01210x^2 + 0.4949x + 21.67$ ($r^2 = 0.64$). Bars indicate ± S.E. (n = 3).

larger particles carries the horticultural benefits of improved aeration and lower D_b for greater efficiency of handling and shipping. In the final measurements, there was an increase in medium size particles at the expense of fine particles in peat moss (0% DMC). This final shift in peat moss was not as desirable since, unlike DMC where the shift from fine to medium particles was present at the start of the crop, the shift in peat moss occurred later during the crop.

Plant growth exhibited a quadratic response with mean shoot dry weight increasing with increasing levels of DMC content in the substrate (Fig. 3). The minimum and maximum shoot dry weights were obtained in the 0% DMC (10.7 g) and 26% DMC (17.1 g) substrates, respectively. Bugbee (2002) also found that greater growth of flowering annuals, herbaceous perennials and woody shrubs occurred in a softwood bark-peat-sand substrate with biosolids compost as compared to the same media without compost. Based on growth in the our study, there were no adverse effects of altered physical

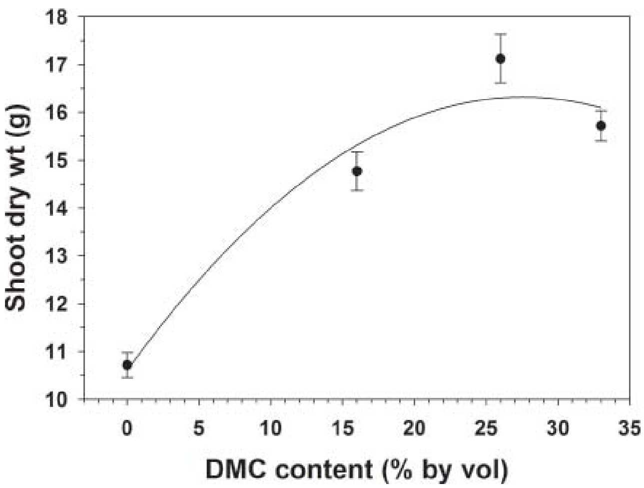

Fig. 3. Effect of dairy manure compost (DMC) used as a substitute for sphagnum peat moss in a 3 sphagnum peat moss:1 perlite container substrate (v/v) on the shoot dry weight of chrysanthemum 'Macumba' (*Dendranthema* × *grandiflora*) grown in a 7.6 cm tall column. The regression equation generated for the best fit model was $y = -0.007523x^2 + 0.4146x + 10.61$ (r^2 = 0.86). Bars indicate ± S.E. (n = 5).

properties, including increased D_b and decreased TP, AS, and AW caused by increasing the ratio of DMC to peat moss in the substrate.

Quantitative levels of physical properties depends on the geometry of the substrate container since the amount of retained water, and consequently AS, depends on the distance above the container base that the properties are measured. Presented in Table 1 are predictions of the initial CC, AS, and AW physical properties of the 0 and 26% DMC substrates for several container types commonly used in the greenhouse and nursery industries. These estimates show how physical property values would change as growers switch from the 7.6 cm (3 in) cylinder used in this study to containers of different depths and lateral shapes ranging from 800 cell plug trays to #1 nursery pots.

Overall, the physical properties of substrates that included DMC did not change any more during plant cultivation than the 0% DMC substrate, indicating that DMC is a highly stabilized compost material equivalent to peat moss. This was further supported by the greater quantity of medium size and lower amount of fine size particles resulting from addition of DMC. Although TP, AS and AW were lower with DMC, plant growth increased with DMC addition. The increased growth may also be attributed to other factors such as the availability of mineral nutrients from the DMC (Jeong et al. 2011). This study showed DMC to be a suitable partial substitute for peat moss in a soilless root substrate with 26 percent providing the best conditions for growth in this study.

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Table 1. A comparison of the calculated initial container capacity (CC), air space (AS), and available water (AW) for several different containers filled with 0 and 26% DMC as predicted using the equilibrium capacity variable model from Milks et al. (1989).

Container volume (type)[z]	0% DMC			26% DMC		
	CC (%)	AS (%)	AW (%)[y]	CC (%)	AS (%)	AW (%)
1.67 cm^3 (800 cell plug)[x]	87.5	1.7	68.8	85.8	1.1	62.7
4.50 cm^3 (273 cell plug)	84.6	4.6	65.9	83.6	3.2	60.5
25.30 cm^3 (128 cell plug)	75.6	13.6	56.9	75.9	11.0	52.8
88.37 cm^3 (48 cell flat)	75.5	13.7	56.8	75.7	11.1	52.6
344 cm^3 (3 in aluminum core)	71.1	18.1	52.4	71.6	15.3	48.5
600 cm^3 (4 in standard pot)	69.2	20.0	50.5	69.9	16.9	46.8
1,930 cm^3 (6 in standard pot)	59.7	29.5	41.0	60.8	26.0	37.7
3,785 cm^3 (#1 nursery pot)	54.7	34.5	36.0	56.0	30.8	32.9

[z]Total porosity (TP) for all container types was 89.2 and 86.9% for 0 and 26% DMC, respectively. Unavailable water (UW) for all container types was 18.7 and 23.1% for 0 and 26% DMC, respectively.

[y]AW was calculated as the difference between CC and UW (CC – UW).

[x]1.67 cm^3 = 0.10 in^3, 4.50 cm^3 = 0.27 in^3, 25.30 cm^3 = 1.54 in^3, 88.37 cm^3 = 5.39 in^3, 344 cm^3 = 20.99 in^3 (0.73 pt), 600 cm^3 = 36.61 in^3 (0.63 qt), 1930 cm^3 = 117.78 in^3 (0.51 gal), and 3,785 cm^3 = 230.97 in^3 (1 gal).

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