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Use of Compost with Onion (*Allium cepa*) Waste and Cattle Manure as Substrate Component for Horticultural Seedlings

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Authors' contributions

This work was carried out in collaboration between all authors. Authors GP and RJB designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author GA managed the literature searches, analyses of the study performed and authors MT and AM managed the experimental process. All authors read and approved the final manuscript.

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ABSTRACT

In the agricultural North-Patagonian region of Argentina, more intensely different alternative substrates of organic origin have begun to be used, which can replace the use of peat to produce vegetable seedlings. The aim of this study was to evaluate the compost obtained from onion waste and cattle manure as a substrate component to produce vegetable seedlings. For a 2- year period (2010-2011), greenhouse trials were conducted. The employed substrates were SCo: commercial substrate, CCE: onion waste compost and cow manure, and M: CCE compost mixture (40%), SCo (40%) + agricultural Perlite (20%). Lettuce (*Lactuca sativa* L.) was used as an indicator crop. Seeds were sown in germination trays, 128 (1) and 200 (2) cells. The experimental design was completely randomized. Substrates were characterized and measurements of leaf area, fresh weight and dry weight were taken during seedling growth. During both trial years, growth parameters were higher

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in the seedlings grown in trays with more cells. The seedlings grown in the commercial substrate and compost had the highest leaf area values. The mixture substrates produced the poorest growth, especially when a lower cell volume used. Use of the onion waste compost and cow manure as a substrate component for seedlings replaced the commercial product with satisfactory results, and reduced the use of a poorly available resource like peat.

Keywords: Composting; wastes; mixture efficiency; sustainable agriculture.

1. INTRODUCTION

The initial growth stage of seedlings of many horticultural species is the most critical time for good production. Emergence speed, uniformity and initial growth rates are crucial for obtaining quality seedlings and reasonable time periods [1]. If substrate volume is limited, root systems are densified to meet the requirements of aerial parts, which means greater oxygen demand per rhizosphere unit [2]. The purpose of any mixture of substrates used to produce horticultural seedlings is to obtain good plant quality during the shortest period and at the lowest production costs possible [3]. Diaz et al. [4], reported that peat extraction and unsustainable harvests have reduced peatland areas worldwide by between 10-20%. This change has occurred worldwide and, currently in Argentina, the application of soilless growing media to produce vegetables and ornamental plants is evident. Today, there is a growing trend to introduce alternative substrates that can replace traditional ones, and work is being done to empower and develop them by commercially, making them more suitable from the environmental point of view [5]. Therefore, adapting and using agricultural waste, and replacing it to be used as substrates or components of substrates in soilless culture, are good practices, provided they are subject to a number of standards and guidelines that fall in line with the Good Agricultural Practices and Sustainable Development [6]. Use of organic materials is beneficial not only for supplying nutrients and improving the physical condition of growth media, but also for removing them from the atmosphere as a pollutant and incorporating them as a resource [7]. Use of waste in the formulation of substrates has a high environmental value as it returns waste materials to the production cycle. In turn, use of these materials reduces the pressure on natural resources, and has no negative effect on the environment [1]. In recent years, different more intensive substrates of organic origin begun to be used to produce forest, ornamental and vegetable seedlings, specifically vermicompost. Vermicompost-based biodegradable municipal waste has proven suitable for producing pepper seedlings (*Capsicum annuum* L.*)* [8]. When evaluating a compost or vermicompost in agriculture, the end-use of treated and stabilized material must be clearly established. Using compost as growing media and/or an organic amendment requires the consideration of potentially hazardous elements, such as Zn, Cu, Ni, Cd, Pb, Hg and Cr. Some allow normal crop growth when available in adequate amounts. However, in other cases, they can cause toxicity, which may affect crop growth and development [9].

Using these materials as components of substrates for soilless culture is one of the most widespread options [10,11,12,13,14,15]. Compost from agricultural waste can be successfully used as an alternative substrate because it promotes seedling growth by contributing micro- and macronutrients, without them having to be supplied through fertilization [16,17,18,19]. In particular, air physical properties which include water ratios, which are extremely important criteria when choosing the shape of the container to be used and the irrigation program to be applied in the selected substrate of the culture system [20]. The physico-chemical and the chemical properties of organic substrates are properties that involve dissolution and hydrolysis reactions of mineral constituents (chemical properties), ion exchange reactions (physico-chemical properties), and biodegradation reactions of organic matter (biochemical properties), [21,22,23]. Biological characterization evaluates the material's biological stability, presence of phytotoxic substances, which can act as inhibitors of germination, and the suppressive capacity of such materials (composted or vermicomposted) against certain plant pathogens [22,24].

In the agricultural North-Patagonian region of Argentina, the most significant advances made in the development of alternative materials include studies on compost prepared with waste onion and cow manure. This is more appropriate than earthworms of household organic waste as a component to formulate substrates to produce lettuce (*Lactuca sativa var. crispa*) seedlings on germination trays cell with a 22 cm^3 capacity [25]. Use of compost as a substrate for seedlings obtained from onion waste would be a viable replacement commercial substrate, which would prolong this alternative stage of horticultural production. As onion compost does not only meet the properties by a culture system, it is important to use mixtures with other materials that will ensure the optimal conditions required for seedling growth. The aim of this study was to evaluate the compost obtained from onion waste and cattle manure as a substrate component in the production of vegetable seedlings.

2. MATERIALS AND METHODS

For two years (2010 and 2011), trials were conducted under controlled conditions in the greenhouses at the National University of Comahue-CURZA, located in the city of Viedma (latitude 40º 49' S) in Argentina. A chapel-like greenhouse was used that had an iron structure and a polyethylene (150-µm thick) roof and sides, and side ventilation. Lettuce (*Lactuca sativa* L.) variety "Prize head" four seasons was used as an indicator crop, and seeds were sown in black polypropylene germination trays (speedling), 128 (1) and 200 (2) cells, with a capacity of 22 cm3 and 12 cm3, respectively. Trays were placed on one-meter high tables. In each cell, 2-3 seeds were placed to ensure germination. The greenhouse was not heated. Temperature and light conditions were suitable for germination and crop development. Irrigation was performed twice daily for 40 days.

The substrates used were:

SCo: GROW MIX commercial substrate used by horticultural producers in the Lower Valley, formed by sphagnum peat moss, vermiculite, calcite, dolomite and wetting agents.

CCE: compost made from onion waste and cattle manure obtained in 2009 and 2010. A mixture was prepared from CCE + perlite (70 + 30%, v/v). Perlite is an inert inorganic substrate used to increase aeration.

M: This mixture was prepared with CCE (40%) + school (40%) + agricultural Perlite (20%)

The experimental design was completely randomized. For the statistical analysis, a triple ANOVA (year x tray x substrate) was applied that considered all the fixed factors. As there was an interaction between factors, the results were subjected to a double ANOVA by considering each year separately for treatments, SCo1, SCo2, CCE1, CCE2, M1 and M2, where: SCo: commercial substrate, CCE: Compost onion-manure and M: Mixing, and where 1 (128 cells) and 2 (200 cells). The treatment means were compared with a Tukey test at 5% [26] (INFOSTAT, 2011). During seedling growth, measurements in the following growth stages were taken: I expanded cotyledon, 1st - 2nd sheet, 2^{nd}-3^{rd} leaf and 3^{rd} - 4^{th} leaf. In each stage, five seedlings were removed per treatment and were conditioned to measure the following variables:

- Leaf area: Samples were packaged and the leaf area was measured in cm2 using the Model 3100 LIAREA METAR equipment.
- According to the cotyledon and true leaf stages, fresh weight and total dry weight were determined.

3. RESULTS AND DISCUSSION

3.1 Leaf Area

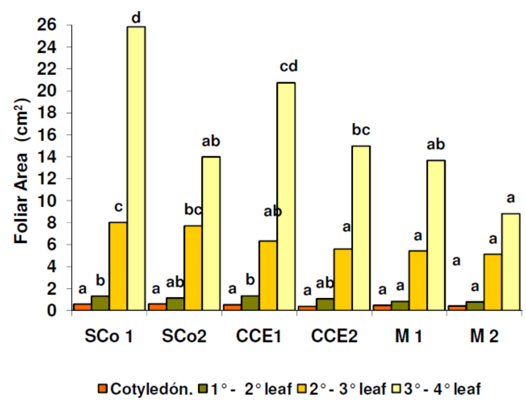
Leaf area is a key variable as it defines the potential photosynthetic capacity of seedlings, which is the primary energy source to produce tissue and nutritional compounds. Leaf area.

Table 1. Physicochemical characterization of substrates

Substrate	pH	E.C. (ds m^{-1})	C (g kg^{-1})	N (g kg^{-1})	P (%)	K (%)	Ca (%)	Mg (%)	Na (%)
SCo (2009)	6,0	0,45	460	8,5	0,09	0,20	0,60	0,54	0,55
SCo (2010)	5,8	0,60	400	7,7	0,10	0,30	0,95	0,62	0,35
CCE (2009)	7,6	1,9	87	9,7	0,18	0,78	1,18	0,49	0,52
CCE (2010)	7,8	1,8	98	9	0,23	0,98	1,76	0,89	0,40
M (2009)	6,9	1,1	300	7	0,045	0,32	0,85	0,32	0,27
M (2010)	7,2	1,4	260	6,5	0,050	0,46	0,77	0,58	0,40

SCo, commercial substrate; CCE: onion-manure compost; M, mixture.

allows the physiological and morphological changes that flow through plants during their cycle to be known. During the 2010 experimental trial, a cell size effect was observed in the 2nd-3rd and 3rd-4th sheets stage (Fig. 1A). The seedlings grown in 22 cm^3 cells had the largest leaf areas, especially in SCo1 and CCE1. In the expanded cotyledon stage, all the treatments obtained the same leaf area.



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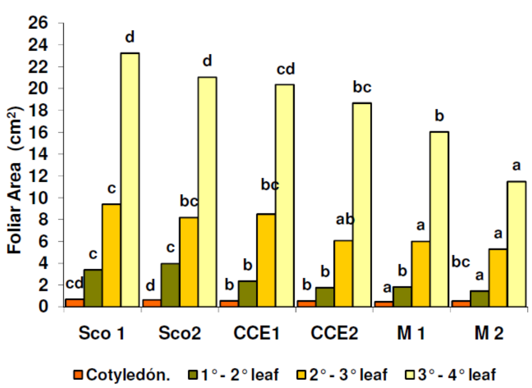


B

Fig. 1. Effect of substrate and cell size on the leaf area of lettuce seedlings in each phenological stage A: 2010, B: 2011 (1) 128 cells and (2) 200 cells. Sco, commercial substrate; CCE, onion-manure compost; M, mixture. Different letters on the same color bars indicate significant differences between treatments ($p \leq 0.05$)

In the 1st - 2nd sheets stage, lower values were observed in M, and no differences between SCo and CCE were found. [25] compared three different substrates: A commercial substrate, a vermicompost of household waste and a waste compost made with onion and manure. The substrate prepared with the onion-manure compost obtained the highest values. In the 2nd-3rd leaves stage, the leaf area was observed with the commercial substrate. In the final stage prior to transplantation, the seedlings grown in SCo and CCE with 22 cm^3 cells showed the largest leaf area, and significantly differed from the remaining substrates. The other treatments obtained similar leaf areas. [27] obtained similar results, and also in lettuce seedlings grown on commercial substrate. In the 3rd-4th leaves stage, the seedlings grown in the larger trays (22 cm^3) with commercial substrate and compost were highlighted. The most favored root physical space examination coincided with that detected by [28]. The SCo2, CCE2 and M1 treatments yielded similar results. Composted manure onion allowed proper lettuce seedling growth. [29] also reported well grown seedlings with compost-based substrate agricultural waste compared with commercial substrates.

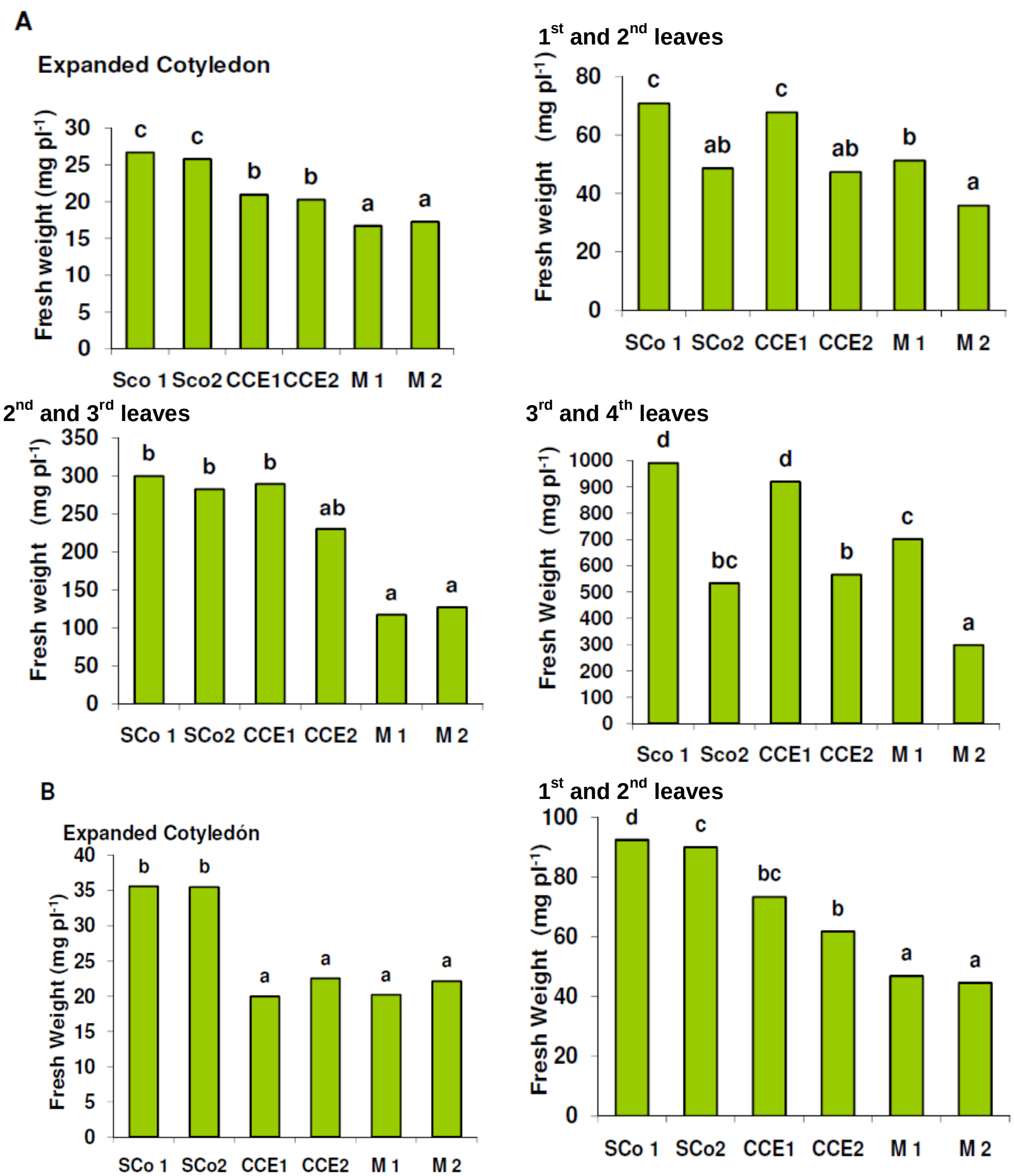
During the 2011 experimental trial, no effect of cell size on the leaf area of seedlings was observed in early growth stages (Fig. 1B). However, in the 2nd-3rd sheets stage, a trend that favored the larger volume cells began to be noticed.

In the cotyledon stage, the seedlings grown on commercial substrate differed significantly from other treatments. CCE1, CCE2 and M2 showed similar development, while M1 proved to be the poorest treatment. In the 1st-2nd leaves stage, the plants grown in the commercial substrate maintained their difference from the rest. This coincides with [30,31], who observed that the substrates prepared with compost produced seedlings had lower initial growth rates. In the most advanced stage, the plants grown in soil with compost obtained similar values to those of the commercial substrate, and no differences between them were found. Substrates M1 and M2 had the lowest values.

In the last stage, the seedlings had a larger leaf area when the 22 cm^3 cells were used. The highest values were detected in SCo1, SCo2 and CCE1, and with significant differences compared to other treatments. The seedlings grown in CCE2 did not differ from M1, and the lowest values were recorded for M2.

3.2 Total Fresh Weight

During the 2010 trial, in the early (expanded cotyledon) stages, the seedlings grown in the compost-based substrate obtained a lower total fresh weight value than those grown in the commercial substrate (Fig. 2A). Commercial products generally offer good nutrient content, which allows rapid initial seedling growth [32]. During this trial and as the season progressed, CCE produced similar results to SCo. The mixture of substrates (M) obtained variable results in all the phenological stages, but did not exceed the performance of the other two substrates. In the 1^{nd}-2^{nd} sheets stage, the total fresh weight of seedlings in all three substrates was significantly heavier in those grown on the trays with the 22 cm^3 cell volume. In this stage, the fresh weight between SCo1 and CCE1 was similar, but was superior to other treatments (Fig. 2A). [33] obtained similar results with the same crop and cells of an equal volume to those employed in this experiment. In t h e 2nd-3rd leaves stage, higher total fresh weight values were observed in the seedlings grown in the commercial substrate and in the compost with both cell volumes.



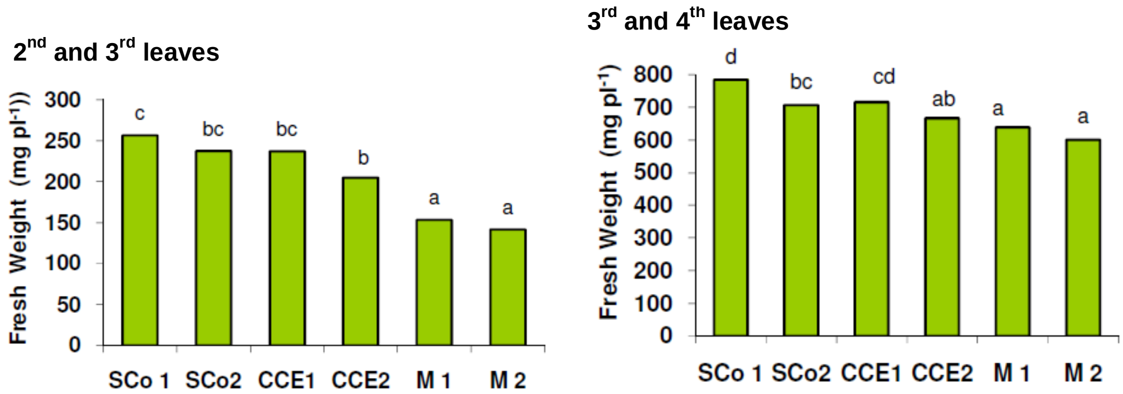


Fig. 2. Effect of substrate and the cell size of the total fresh weight of lettuce seedlings in each phenological stage A: 2010, B: 2011 (1) 128 cells and (2) 200 cells. Sco, commercial substrate; CCE, onion-manure compost; M, mixture. Different letters on bars indicate significant differences between treatments ($p \leq 0.05$)

In the last stage, SCo1 was evaluated and CCE1 had the highest total fresh weight values, and showed significant differences from the other substrates. Some authors indicated that compost can be used in amounts up to 66.7% (v/v) without adversely affecting seedlings. No differences were found between CCE2 and SCo2. M1 had similar weights to what the SCo2 treatment yielded. The largest cell volume further enabled seedling growth before being transplanting. The lower values of the parameters measured in the lettuce seedlings grown in the substrate mixture (M1 and M2) differed from those observed by [34,20], who obtained very favorable results in the seedlings that they grew in compost mixtures and commercial substrate and/or sphagnum peat. This behavior could be associated with a reduction in the pH and salinity levels brought about by adding the commercial product. Lower, but not significant, yields for CCE1 were observed compared to the commercial substrate, possibly due to the compost's increased salt content and a higher pH, as suggested by [35] and [36]. These authors believe that optimum values could range between 5.2 and 6.3. However in the more advanced crop stages, the CCE1 substrate obtained similar yields to the commercial substrate, probably due to the N, P, K, Ca and Mg levels, which were higher than those of the commercial substrate.

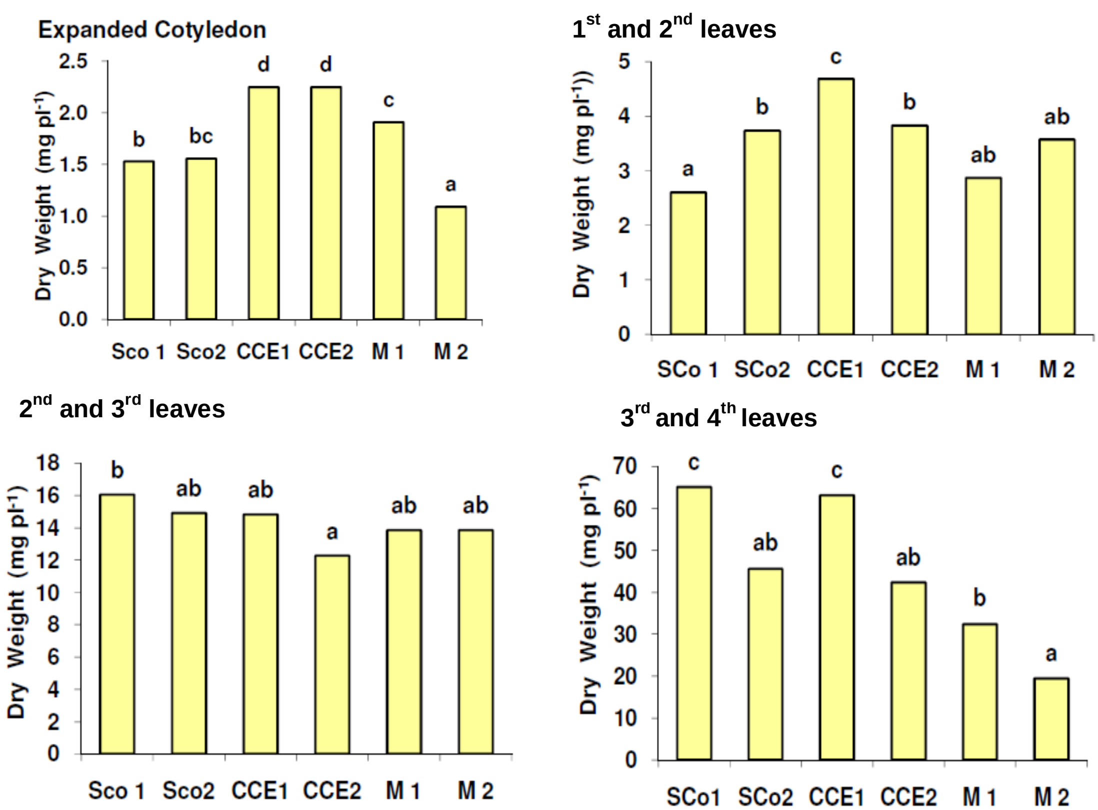
These results indicate that compost can be considered an important source of essential nutrients for growing seedlings in soilless substrates. During the trial conducted in 2011, in the cotyledon stage the seedlings grown on SCO obtained the highest fresh weight values, which coincided with leaf area; No statistically significant differences were detected between M and CCE (Fig. 2 B).

In the 1st-2nd sheets stage, once again the positive effect of the commercial substrate was reflected, which produced more total weight fresh saplings, and SCo1 differed from other treatments; SCo2 and CCE1 all had similar weights. M1 and M2 in the mixtures obtained the lowest values. In the 2nd-3rd sheets stage, no differences among the SCo1, SCo2 and CCE1 treatments were obtained, but they were superior to other treatments. No differences for CCE2 were found with CCE1 and SCo2. In this stage, the mixtures once again obtained poorer growth values. In the 3rd-4th leaves stage, and coinciding with the results obtained in 2010, seedlings grew better in the commercial and compost substrates (SCo1 and CCE1) in the trays with a larger volume of cells (22 cm^3). Those grown in SCo2 and CCE2 had similar values. Mixtures M1 and M2 did not allow adequate lettuce seedling growth, and obtained the lowest fresh weight values. Although lower values were obtained with the CCE compost for the growth substrate parameters, these differences were not significant compared with the commercial substrate. These results were consistent with the behavior observed during the 2010 trial, and are probably related to the higher salt concentration and pH (Table 1). This behavior has also been observed by [34,37,38] when they studied the influence of different amounts of compost (organic waste from distinct backgrounds and characteristics) in mixtures of substrates used to grow various horticultural species. [39] have also indicated that moderate salt concentrations in substrates can cause stunted plant development.

3.3 Total Dry Weight

During the 2010 trial, in the expanded cotyledon and the 1st-2nd sheets stages, the highest total dry weight values were obtained in the seedlings grown in the soil with the compost CCE1 (Fig. 3 A). In the 2nd-3rd sheets stage, similar values between treatments were found; Only significant differences between the total dry weight of the seedlings grown in SCo1 and CCE2 were detected. In the 3rd- 4th sheets stage, the total dry weights of the seedlings grown in CCE1 and SCo1 were significantly higher than in the other treatments. M2 obtained the lowest total dry weight value.

[40] measured the growth rate in a lettuce crop using a substrate-based compost plant material and a commercial substrate as the growth medium. These authors concluded that the dry weight of seedlings increased when a higher proportion of composted materials was used. In the stage, similar dry weights were detected in all the tested substrates. In the 1st-2nd sheet stage, the previous year, no difference between the commercial substrate and compost was found for total dry weight of seedlings. Mixtures M1 and M2 had the lowest values (Fig. 3 B). In the 2nd-leaves stage, the highest dry weight value was detected in SCo1 and CCE1, and no difference was evidenced among SCo2, C CE2, M1 and M2. As in the previous year, the last growth stage showed the highest dry w eight values in the seedlings grown in the commercial substrate and CCE1, which had significant differences compared to the other substrates. SCo2, CCE2 and M1 displayed a similar behavior to each other. The lowest dry weight value went to M2. These results coincide with [1], who compared the growth of pepper substrates prepared with peat, composted plant material and a commercial product. These authors concluded that the seedlings grown in the commercial substrate and the substrate with a highest compost proportion were those with the highest dry weight values.



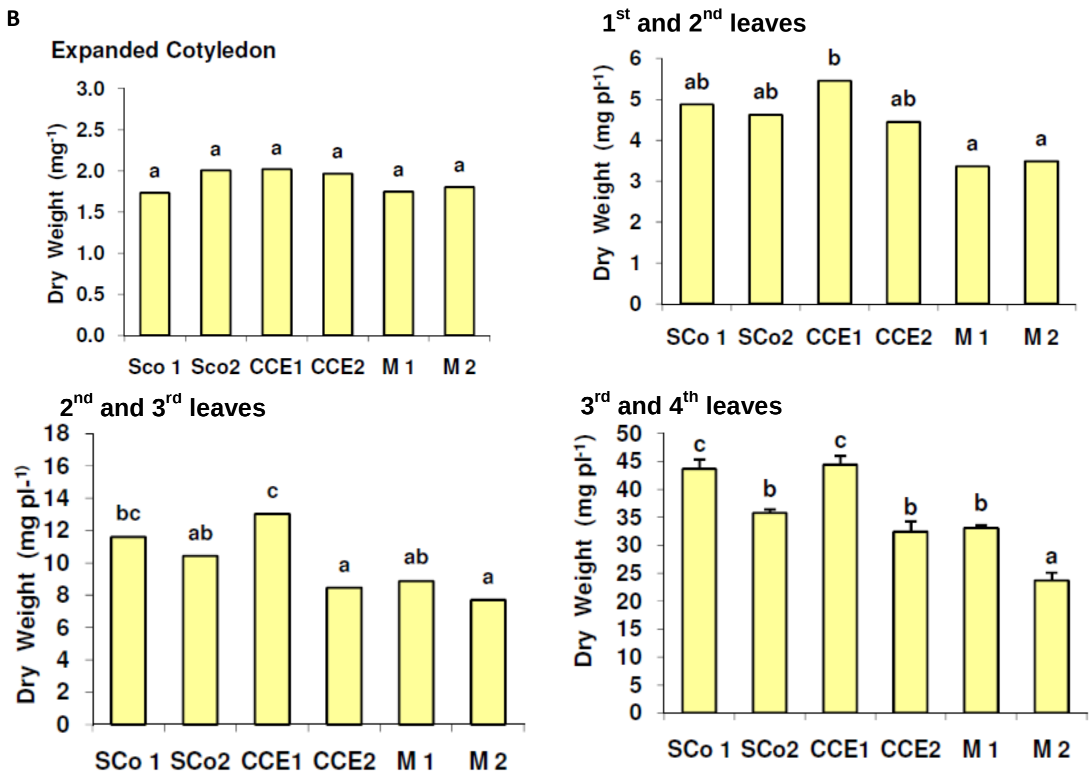


Fig. 3. Effect of substrate and cell size on the total dry weight of seedlings of lettuce in each phenological stage. A: 2010, B: 2011 (1) 128 cells and (2) 200 cells. Sco, commercial substrate; CCE, onion-manure compost; M, mix Different letters on bars indicate significant differences between treatments ($p \leq 0.05$)

4. CONCLUSION

During both trial years, growth parameters leaf area, fresh weight and dry weight were hi ghe r in the seedlings grown in trays with the largest cell volume. Obviously the more physical space provided by cells trays favored root system growth, and allowed greater absorption, and better transport of water and nutrients, which increased crop yield. The seedlings grown in the commercial substrate and compost gave the ighest leaf area values. The mixture substrate (M1 and M2) resulted in poor growth, especially when the smaller cell volume was used. In early phenological stages, higher fresh and dry weight values were recorded toward the end of the cycle, and the commercial product seedlings grown in compost obtained similar values, and in the case of the dry weight exceeded it. This would indicate that although the commercial substrate was initially the most appropriate one, when the culture was rooted, compost could replace it with satisfactory results. The use of compost prepared from a mixture of onion waste and cattle manure as a substrate component f o r the production of vegetable seedlings could replace commercial substrates with satisfactory results. Thus the use of a resource that is poorly available, e.g. peat, could be reduced.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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