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Photosynthesis, growth, and yield in strawberry with sheep manure compost and peat

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Abstract

Compost enables sustainable handling of home organic residuals and decreases cost production of small-scale horticultural systems. The objective of this research was to analyze the effect of compost addition to soilless media on the growth, yield, and physiology of three strawberry cultivars. The Mexican cultivars 'Jacona' and 'Zamorana' and the commercial 'Festival' were grown inside a glasshouse on either of two media mixtures: peat+perlite (1:1; v/v) or compost+peat+perlite (2:1:1; v/v). Compost was made of sheep manure and the Steiner solution was the mineral source. Readings of photosynthesis rate, stomatal conductance, transpiration rate, soil-plant analysis development (SPAD) units were performed periodically and dry weight from organs was determined six times. The addition of compost resulted in less total plant dry weight during the fruiting season and lower SPAD values throughout the experiment; however, photosynthesis was only affected by compost additionjust before the fruiting period compared with plants growing without compost. Dry matter remobilization during fruiting apparently explained the lack of effect of compost addition on total plant yield. As a conclusion, SPAD units and total plant dry matter were negatively affected by sheep manure compost during strawberry fruiting, but total plant yield was not affected by compost apparently explained by dry matter remobilization in the plant towards the fruit, and from roots and leaves.

Keywords: *Fragaria x ananassa*, dry matter partitioning, photosynthesis, SPAD units, stomatal conductance.

Introduction

Population will continue to grow while *per-capita* arable land is most likely to decrease because of environmental, social, or economic issues. Not only is the world population projected to reach 9.7 billion people in 2050, two billion more than in 2019, but also life expectancy will increase from 72.6 years in 2019 to 77.1 years in 2050 (UN [United Nations], 2019). Also, even though arable land will increase, mainly in developing countries, this increase will be below the population growth curve, resulting in a net decrease of world *per-capita* arable land from about 0.23 to roughly 0.19 ha per person in 2050, with lower numbers in developing countries than in those developed ones (Bruinsma, 2009). This scenario shows a future where food production, must increase, though constrained by consumer exigency for higher food quality, food safety, and environmental sustainability (Godfray et al., 2010). Besides, if an increase of about 10 – 67 % in urbanization relative to the base year of 2013 is considered, as mentioned by Li, et al. (2019), and also a rural to urban population ratio decrement from 0.81 in 2018 to 0.32 in 2050, as projected by FAO (Food and Agriculture Organization, 2020), the urban and peri-urban horticulture must be considered to reach the food security levels for growing populations.

Urban horticulture has been part of city landscapes for a long time however, this activity has been analyzed as part of

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the sustainability and food security of those areas in recent decades. Godfray et al. (2010) stated three big challenges faced by the world regarding food production and consumption: one will be the necessity to feed more people, another is to do it environmentally and socially sustainable, and the third one is to have available food for the poorest. These authors also proposed closing the yield divide, not only among regions but also in crops, changing dietary habits, reducing food wastes, and expanding aquaculture as a few options to reach global food security. Urban and peri-urban horticulture in all those variants mentioned by Mok et al. (2014) and Samangooei, et al. (2016) are just examples of the possibilities which may help to get these goals in order to reach food security in growing cities throughout the world. However, much research must be done to configurate the more efficient plot to produce food in cities in a sustainable manner.

Urban horticulture should meet technical, environmental, social, and economic criteria to become an option to produce food. Samangooei et al. (2016) performed a comparison between soilless and soil-based systems for urban horticulture. Considering several issues for social, economic, and environmental factors of development, the authors revealed that even though soilless horticulture is more productive by square meter, soil-based systems appear to be more environmentally and socially beneficial, and also more affordable, than the soilless systems. In urban food production systems like those mentioned by the authors, crops with shallow roots like the strawberry and compost-based media can increase the sustainability in the urban food production. On the other hand, the use of compost as growing substrate increases environmental value to the cities of the soil-based urban horticulture as it allows the recycling of organic matter at home or in the cities which would be otherwise a source of pollution (Jara-Samaniego et al., 2017; Samangooei et al., 2016; Tavera, Escamilla, Alvarado, Salinas, & Galicia, 2014) and can also decrease the cost already included in some production systems to help the sustainable development of urban and peri-urban areas (Alvarado-Raya et al., 2016; Jara-Samaniego et al., 2017; Tavera et al., 2014). On the other hand, the strawberry plant is capable of growing in thin layers of substrate, offering the possibilities for a light system suited for roofs, buildings or even vertical farming (Wortman et al., 2016); however, because the difference in physical, chemical, and biological characteristics of the compost depend on the raw material and the composting process, also because of the difference of the cultivars in their response to the growing system, much research must be done before selecting the proper strawberry urban production system with compost based media (Gruda, 2019; Wortman et al., 2016).

The response of the strawberry plant to compost-based substrates could vary. Some authors have found positive increases in strawberry plant growth and yield by using compost as soil supplement (Shehata, et al., 2011; Wang y Lin, 2002); others have found no statistical differences in strawberry yields by using organic wastes as soil supplements, either composted or not (Balci, et al., 2019) nor when comparing organic systems to conventional systems using vertical hydroponics (Wortman et al., 2016). Other authors have found that strawberry response depends on the characteristics of the growing media (physical, chemical, and biological) (Lloyd, et al., 2016) or the compost type and concentration in the media (Alvarado-Raya et al., 2014). Regarding the mechanisms or explanations of the compost effects, there are also different hypothesis among different studies, some of them emphasize the effect on the physical, chemical, and biological characteristics of the media (Lloyd et al., 2016) and some others have pointed out the physiological benefits from plant growth promoters in the rhizosphere (Jindo et al., 2012) or in plant chlorophyll content, photosynthetic activity, and enzymatic activity (nitrate reductase) (Naderi y Ghadiri, 2013; Wang y Lin, 2002).

Based on the potential of compost in sustainable strawberry production for food security in urban and peri-urban areas, the diverse effects of compost on strawberry growth and yield, and the need of information regarding strawberry physiology in response to compost-based media, this research was conducted to analyze the effect of compost addition to soilless media on the growth, yield, and physiology of two Mexican cultivars of strawberry under the hypothesis that compost addition to the media increases photosynthesis and thus strawberry growth and yield.

Materials and Methods

Experimental organization

Plants of cultivars 'Jacona' and 'Zamorana' from the Colegio de Postgraduados (CP) strawberry breeding program in central Mexico and plants from the commercial variety 'Festival' (University of Florida) were used in this research. Bare-root plantlets were obtained from the CP nurseries and chilled at 1.0 °C throughout 98 d before planting on March 1, 2013, in black plastic bags (3.0 kg) with either two combinations of growing media: peat+perlite (1:1; v/v) or compost+peat+perlite (2:1:1; v/v). Compost was made of sheep manure. Electric conductivity and pH of substrates were between 0.46 to 0.67 $dS \cdot m^{-1}$, 3.9 to 4.2 for non-compost media; and 1.56 to 1.84 $dS \cdot m^{-1}$, 7.1 to 7.4 for compost-based media. Bags were placed inside a glasshouse (19° 27' North; 98° 54' West; 2 250 meters above sea level) and plants were grown from March-2013 to April-2014 with a Steiner solution as mineral source with an EC of 0.5 $dS \cdot m^{-1}$, pH 5.0-5.5, and based on $CaNO_3$, KNO_3, monopotassium phosphate (MKP), $MgSO_4$, KSO4, $(NH_4)_2SO_4$, and a commercial combo for micronutrients.

Six treatments resulting from the combination of growing media and cultivars were considered in this experiment. Each treatment had 20 replications and one plant/bag was an experimental unit. Treatments were distributed inside a glasshouse in a CRD with arrangement as a split-plot design considering substrate as the main plot and cultivar as the subplot. Collection data began three months after planting in all treatments. Five readings with the portable LI-6400 photosynthesis system (LI-COR; Lincoln, NE), and recording photosynthesis rate, stomatal conductance and transpiration rate were performed from June 5, 2013 to March 28, 2014 (10:00 h to 13:00 h) using the central leaflet of a healthy and fully extended leaf. Water use efficiency was also calculated. Chlorophyll content was evaluated six times from June 11, 2013 to April 9, 2014 (10:00 am to 12:00 pm) by means of a Minolta SPAD-502 meter (Minolta Camera Co. Ltd., Osaka, Japan). Three whole young leaves per plant (nine leaflets) were used for each chlorophyll reading.

Plant growth was analyzed by determining matter partitioning on each of four plant organs: root, crown, leaf, and flower+fruit. Six destructive samplings were made from June 17, 2013 to April 9, 2014 for root, crown, and leaf structures; flower+fruit structures were analyzed four times throughout the experiment (from November 4, 2013 to April 9, 2014). Plants were collected, dissected and structures were separately dried at 70 °C to reach constant dry weight. In order to determine yield, fruits were collected weekly at full maturity stage (Rahman, et al., 2016) from October 3, 2013 to March 23, 2014. Fruit weight was recorded with a digital scale.

Data analysis

Data analysis was performed by SAS version 9.0 (SAS Institute Inc.; Cary, NC) using the mixed procedure with a split-plot model with substrate as main plot and cultivar as sub-plot. Whenever statistical significance was detected in a factor for any variable, a Tukey test (α = 0.05) was performed for media separation.

Results

Field experiments and data collection comprised 13 months after planting on March 1, 2013. During this period, plants were in vegetative growth through spring and summer, had a fall flower induction (approximately in September) and a fall-winter-spring fruiting season.

Effect of growing media on plant growts

Growth of strawberry plants assessed as increment of total dry weight was not affected by the growing media through the first eight months after planting. Differences became evident until December 26, 2013, almost nine months after planting, and from there on plants grown in media without compost had the highest dry matter values when compared with plants from compost-based media (Table 1). Based on the periodic assessment of dry matter accumulation by plant structure (Figure 1) it was evident that only root dry weight was consistently affected by media throughout the growing season as plants grown in media without compost achieved statistically more root dry weight than plants grown with compost (Figure 1G). Also, leaf dry weight was influenced by growing media only after the fruit began to grow on the plant. In this case, leaves from plants growing in compost-based media attained less dry weight than those in media without compost (Figure 1C). A decrease of dry weight of root, crown, and leaves was also evident after plants began to fruit and such dry matter decrement was present in all treatments and plant structures, but with higher intensity in roots from plants grown in media without compost and leaves from plants grown in media with compost.

Table 1. Monthly total dry weight from strawberry plants of three cultivars grown in two media mixtures.

	Plant total dry weight (g)					
	June-17	Aug-10	Nov-4	Dec-26	Feb-13	Apr-9
Media (M)						
Peat:perlite (1:1)	10.5±1.0[z]	23.1±2.0	41.7±2.6	50.0±1.9a[y]	52.3±1.4a	53.4±1.7a
Compost:peat:perlite (1:1:1)	9.9±0.8	18.6±1.2	46.8±3.1	39.8±3.1b	46.3±1.3b	46.8±1.7b
Significance	ns[x]	ns	ns	*	**	**
Cultivar (C)						
Festival	10.1±0.9	20.1±3.1	40.3±2.4b	40.7±4.5b	47.2±2.6b	48.9±3.2b
Jacona	9.1±1.0	19.5±2.2	42.2±4.7b	42.1±4.7b	48.1±0.9b	47.3±1.5b
Zamorana	11.5±1.2	23.0±0.7	50.1±2.2a	52.0±2.1a	52.6±1.7a	54.1±1.3a
Significance	ns	ns	*	*	*	*
M x C	ns	ns	*	ns	*	***

[z]Values are the mean ± the standard error. [y]Means with the same letter in the column and factor are not statistical different (Tukey = 0.05). [x]ns: Non- significant; *Significant at 0.05; **Significant at 0.001; ***Significant at 0.0001.

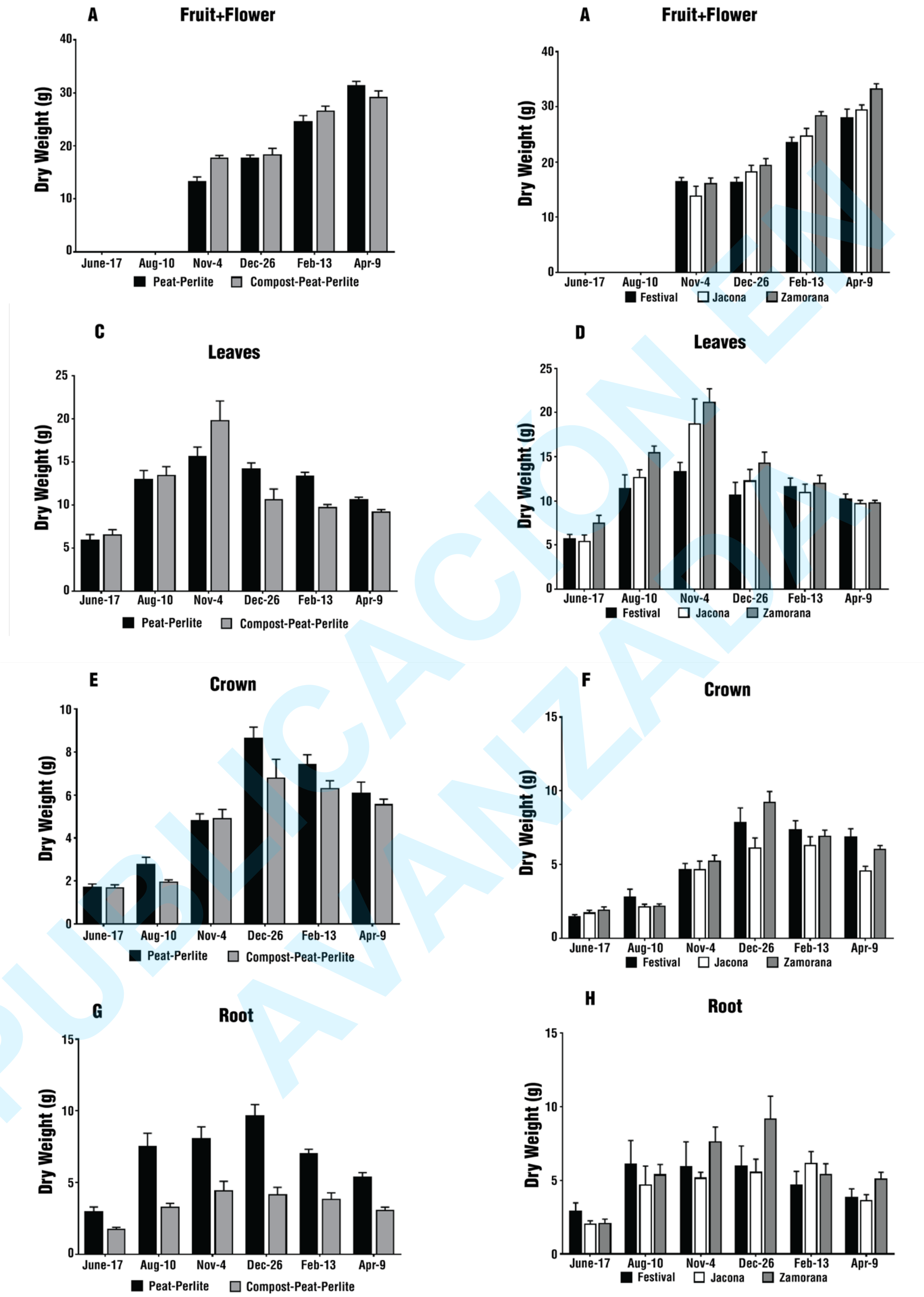

Figure 1. Periodical dry weight accumulation in plant organs of three strawberry cultivars (B, D, F, H) grown in pots with two media mixtures (A, C, E, G). Error bars are standard errors.

Table 2. Periodical SPAD values for three strawberry cultivars grown in two media mixtures.

	SPAD Values					
	June-11	Aug-6	Oct-10	Dec-26	Feb-10	Apr-9
Media (M)						
Peat:perlite	38.8±0.2a	42.3±0.2a	48.3±0.2a	50.5±0.2a	53.4±0.2a	47.8±0.2a
Compost:peat:perlite	34.7±0.3b	36.6±0.2b	38.4±0.3b	43.4±0.4b	46.6±0.3b	44.7±0.2b
Significance	***[x]	***	***	***	***	***
Cultivar (C)						
Festival	37.6±0.2a	39.1±0.5b	43.9±0.7	47.2±0.6	51.0±0.4a	46.2±0.3b
Jacona	36.5±0.4b	39.3±0.4ab	43.0±0.8	46.2±0.6	49.8±0.4b	47.0±0.4a
Zamorana	36.2±0.6b	40.0±0.5a	43.2±0.8	47.3±0.5	49.2±0.7b	45.6±0.3b
Significance	*	*	ns	ns	***	***
M x C	***	ns	ns	*	***	ns

Values are the mean ± the standard error. [y]Means with the same letter in the column and factor are not statistical different (Tukey = 0.05). [x]ns: Non- significant; *Significant at 0.05; **Significant at 0.001; ***Significant at 0.0001.

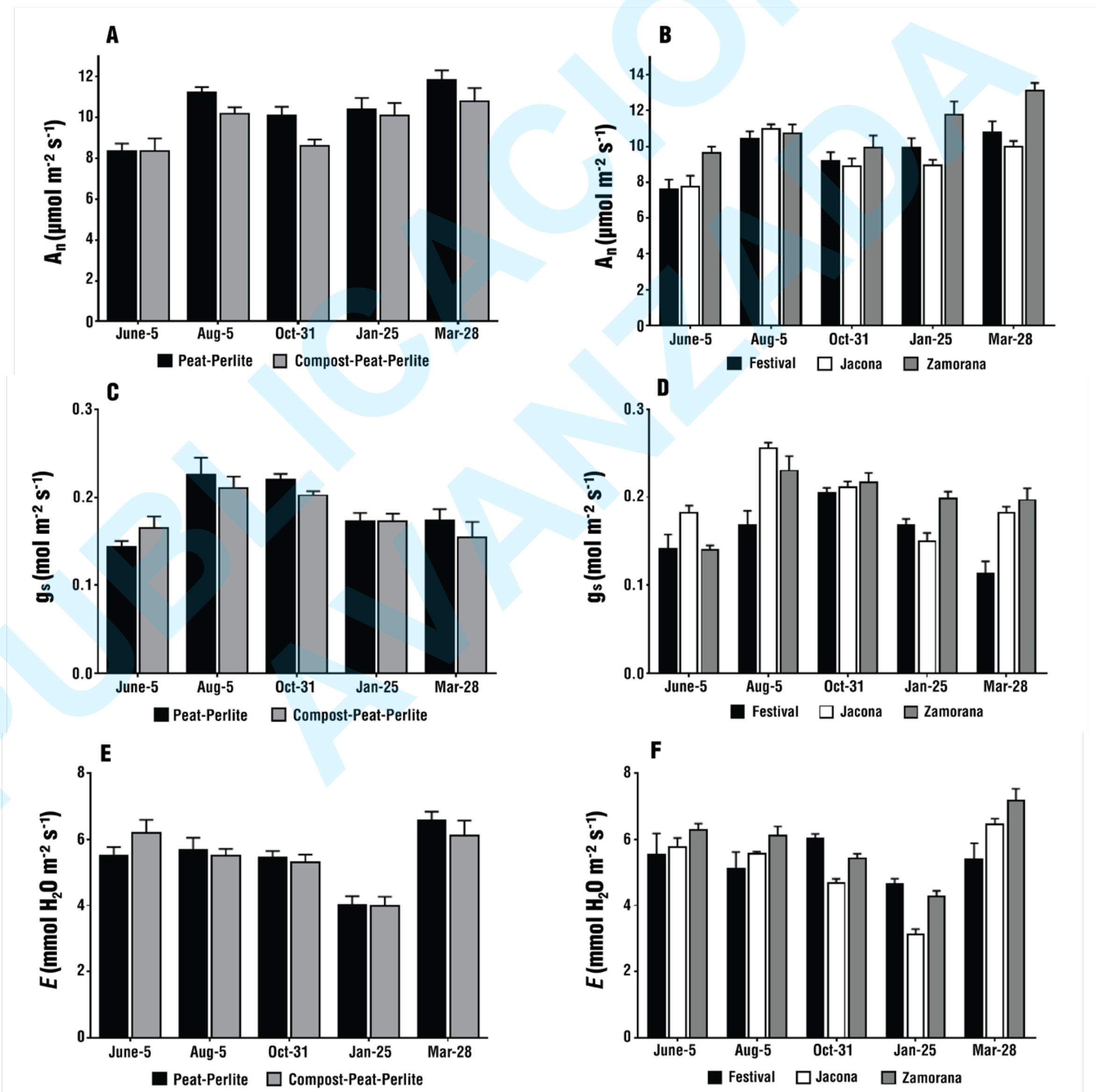

Figure 2. Leaf gas exchange and stomatal conductance for three strawberry cultivars (B, D, F) grown in pots with two media mixtures (A, C, E). Error bars are standard errors.

Effect of growing media on SPAD values and leaf physiology

Independently of the growing media, the soil-plant analysis development (SPAD) values increased consistently from June 2013 to February 2014. Thereafter, at the end of the experiment, the values leveled off (Table 2). It was also evident that SPAD values were consistently higher in leaves from plants grown without compost than in those grown in compost. Differences in net photosynthesis rates were only detected in August and October of 2013, which were five and seven months after planting and previous or concurrent to flower induction and flowering. During these dates, plants without compost had the higher photosynthesis rates (Figure 2A).

Stomatal conductance was not affected by the growing media during the experiment, except at the beginning of fruiting (October of 2013) when the highest values were found in plants grown in media without compost (Figure 2C). Looking at the whole growing season, stomatal conductance increased during flower induction and beginning of fruiting. Then, such variable decreased to remain just over the initial values without effect of compost. Transpiration rate was not affected by media; however, this variable had significant variations throughout the growing season (Figure 2E). Transpiration remained constant until late October of 2013, which is mid-autumn in central Mexico and coincided with the beginning of fruiting in this experiment; thereafter the variable decreased significantly in January 2014, corresponding with mid winter and middle fruiting season, to increase again in late March 2014 or beginning of spring.

As a result of the balance between net photosynthesis and transpiration, instantaneous water use efficiency (WUEins) showed no differences among plants growing either with or without compost throughout the experiment (Table 3); however, comparing sampling dates, WUEins showed higher values at late January 2014 (mid-winter; midst of fruiting) and early August 2013 (flower induction) with the lower values found just three months after planting (June 2013), which was a very active vegetative growth season.

Effect of growing media on yield

Even though fruit weight was significantly higher in plants grown in media without compost, the addition of compost to the media had no effect neither in total number of fruit per plant nor in total yield of the plant (Table 4). Variations from October 2013 to March 2014 are shown for fruit weight in Figure 3A and for plant yield in Figure 3C. There was evidence of an increase in both variables in January and February. Also, variation in fruit size during fruiting was more noticeable in plants grown without compost than in plants grown with compost, while plant yield behaved almost similar in both media, excepting the two first months of fruiting. Fruit weight was significantly affected by media only in the middle of the fruiting season (January and February), when the higher yields and number of fruits were registered for the plants; in such case, media without compost resulted in heavier fruits.

Plant growth among cultivars

Differences on growth among cultivars were evident only after eight months from planting when cultivar Zamorana attained more total dry matter than the other two cultivars and continued to do so during the rest of the growing period (Table 1). Also, whenever differences were observed among cultivars from the dry weight assessed for any plant structure, 'Zamorana' had more dry weight than the other two cultivars, which only on some occasions 'Festival' equaled

Table 3. Instantaneous water use efficiency for three strawberry cultivars grown in two media mixtures.

	WUEins (µmol $CO_2 \cdot m^{-2}$ $s \cdot mmol^{-1}$ $H_2O \cdot m^{-2}$ s^{-1})				
	June-5	Aug-5	Oct-31	Jan-25	March-28
Media (M)					
Peat:perlite (1:1)	1.61±0.12[z]	2.13±0.17	1.86±0.08	2.77±0.14	1.84±0.07
Compost:peat:perlite (1:1:1)	1.39±0.13	1.93±0.09	1.65±0.10	2.66±0.13	1.86±0.12
Significance	ns[x]	ns	ns	ns	Ns
Cultivar (C)					
Festival	1.63±0.24	2.26±0.27	1.52±0 .07b[y]	2.40±0.20b	2.13±0.10a
Jacona	1.33±0.12	1.99±0.06	1.94±0.13a	3.01±0.08a	1.56±0.03c
Zamorana	1.54±0.02	1.84±0.06	1.81±0.09ab	2.74±0.08ab	1.85±0.05b
Significance	ns	ns	*	*	**
M x C	ns	ns	ns	ns	ns

Values are the mean ± standard error. Means with the same letter in the column and factor are not statistically different (Tukey = 0.05). ns: Non-significant; * Significant at 0.05; **Significant at 0.001; ***Significant at 0.0001.

this cultivar (Figures 1B, 1D, 1F and 1H). Differences among cultivars in dry weight from each plant structure depended on the phenological stage with differences found in leaves only before fruiting (Figure 1D) and differences found in roots only during fruiting (Figure 1H). Regarding differences among cultivars on crown dry weight, these were found in two periods, one before flower induction and the other during fruiting (Figure 1F).

SPAD values and leaf physiology among cultivars

SPAD values increased consistently in the three cultivars from June 2013 through February 2014 and then decreased in April 2014. There was no cultivar with consistently higher SPAD values throughout the experiment. However, 'Festival' and 'Zamorana' attained higher values before flower induction and 'Festival' and Jacona were similar in this variable at the end of the experiment (Table 2).

Differences in photosynthesis were detected only in June 2013 (before flower induction) and January and March 2014 (peak of fruiting season). 'Zamorana' always registered the highest rates of net photosynthesis on these dates (Figure 2B). Stomatal conductance was also higher in the Mexican cultivars 'Zamorana' and 'Jacona' with only one date without statistical differences among cultivars, which corresponded to the beginning of fruiting (Figure 2D).

Transpiration rate and WUE_{ins} showed similar tendencies as those described for media mixtures, thus all cultivars had a decrement in transpiration in mid-winter and then registered an increase in this variable in early spring corresponding with an inverse behavior in WUE_{ins} (Figure 2E, Table 3). Differences in transpiration rates and WUE_{ins} among cultivars were detected only after fruiting began; here, 'Festival' had the highest rates on October 2013 and January 2014 with 'Zamorana' having the highest transpiration in March 2014 (Figure 2E). As a result, 'Jacona' registered higher values for WUE_{ins} than 'Festival' through the first half of fruiting, with inverted relationship at the end of the experiment (Table 3).

Yield among cultivars

Total yield in grams per plant was higher in the cultivar Zamorana than in the other two. This higher yield was more the result from fruit weight as fruits of 'Zamorana' had higher weight than those of 'Festival' and 'Jacona', but there were not any differences in fruit number per plant among the three cultivars (Table 4). Taking into account the distribution of yield throughout the experiment (Figures 3B and 3D), high increments were evident in fruit weight in January 2014 and plant yield in February 2014. Regarding plant yield, there were only two out of six dates when differences among cultivars were detected. In such cases, Mexican cultivars had higher yields than 'Festival', where cultivar 'Jacona' had higher yields before winter in December and 'Zamorana' dominating at late winter in February (Figure 3D). Fruit weight got differences among cultivars in four out of six sampling dates with the Mexican cultivars dominating this variable and 'Zamorana' prevailing with the heavier fruits (Figure 3B).

Discussion

Sheep manure compost in the growing media did not affect total plant dry matter accumulation in strawberry during the vegetative period (first eight months) but had a significant negative impact in this variable during fruiting (Table 1). Previous research has found a positive effect of compost on the total strawberry dry matter accumulation when only water has been used for irrigation, which was observed using either compost from sheep manure

Table 4. Total yield and fruit weight for three strawberry cultivars grown in two media mixtures.

	Total plant yield (g)	Total number of fruit per plant	Average fruit weight (g)
Media (M)			
Peat:perlite	355.5±11.8	29.8±1.2	12.2±0.3a
Compost:peat:perlite	330.7±15.6	28.7±1.0	11.6±0.3b
Significance	ns^{x}	ns	*
Cultivar (C)			
Festival	317.4±18.2b	30.2±1.6	10.6±0.2c
Jacona	333.8±14.7b	27.7±1.3	12.2±0.1b
Zamorana	378.2±13.4a	29.9±1.1	12.9±0.3^{a}
Significance	*	ns	***
M x C	*	*	ns

Values are the mean ± standard error. Means with the same letter in the column and factor are not statistically different (Tukey = 0.05). ns: Non- ignificant; *Significant at 0.05; ***Significant at 0.0001.

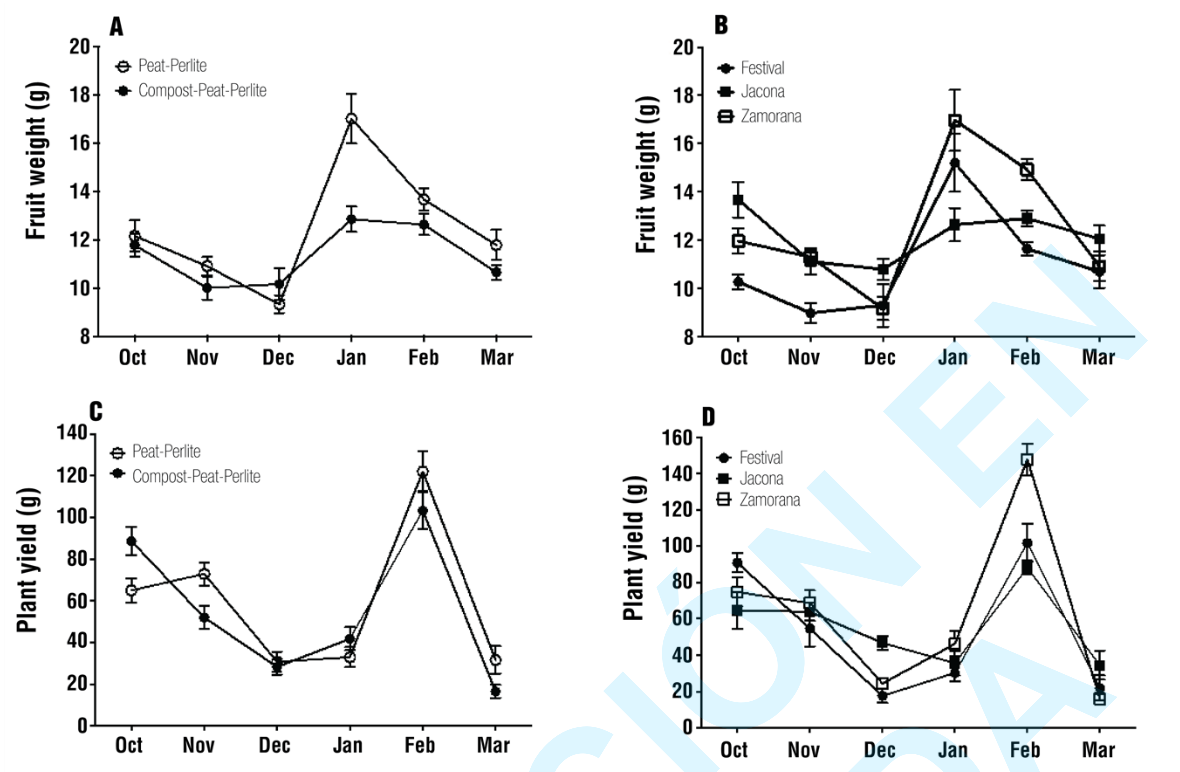

Figure 3. Fruit weight and plant yield for three strawberry cultivars (B, D) grown in pots with two media mixtures (A, C). Error bars are standard errors.

or from agricultural wastes (Alvarado-Raya et al., 2014; Wang y Lin, 2002). Also, Lloyd et al. (2016) found that positive effects of compost on strawberry plant growth and yield may be expected when the plant grows in less-than-optimal environmental conditions, including climate and soil characteristics and Vandecasteele, Debode, et al. (2018) stated that N, P, and K need to be adjusted in the fertigation solution when strawberry is grown in compost-based media to get the best performance of the strawberry soilless system. In our experiment, all treatments were watered with a Steiner solution and the availability of nutrients could explain the lack of effect of compost during the vegetative period.

During the fruiting period in strawberry, the dry weight allocation behavior may switch to developing fruits (Fernandez et al., 2001). In our experiment, compost had a negative impact in plant dry matter accumulation during this high demanding plant stage (Table 1). Electric conductivity of substrates during this experiment were in adequate levels for strawberry growth (0.46 to 0.67 and 1.56 to 1.84 $dS \cdot m^{-1}$ for non-compost and compost-based media, respectively); however, pH was in the alkalinity level for compost-based media (7.1 to 7.4), compared with pH for peat-perlite substrate (3.9 to 4.2). Kaya, et al. (2002) found a decreasing dry matter accumulation and fruit yield in strawberry at high pH (8.5) compared to low pH (5.5). High pH in the substrate has also been related with low SPAD units in strawberry (Roosta, 2014). In the present work, the lower values of SPAD units and the lesser total plant dry matter accumulation during the fruiting period in plants grown in compost could be the result of pH above 7.0 (Tables 1 and 2).

Although SPAD units were lower in the plants grown in compost throughout the experiment, the yield was affected only at the beginning of the season and fruit size only at mid-season; however, total plant yield was not affected (Figures 3A, 3C and Table 4). Photosynthesis rates were basically unaffected by treatments, except for August (previous floral induction time) and October (flowering) when plants grown without compost were more photosynthetically active. Stomatal conductance, transpiration rate, and consequently instantaneous water use efficiency, remained unaffected by treatments during fruiting (Figures 2A, 2C, 2E, and Table 3).

Although a higher photosynthesis activity during fruiting season would be expected for plants grown without compost as they accumulated more total dry matter in this period, results of the present work showed no differences in leaf physiology. Blanke (2009) stated the primordial importance of fruit as a sink for assimilates and Fernandez et al. (2001) found a switch of dry matter allocation to fruit and flower after these organs appeared in the strawberry. In our experiment, dry matter decreased in plant organs during fruiting (Figure 1) with deeper decrements in leaves from plants grown in compost (Figure 1C) and

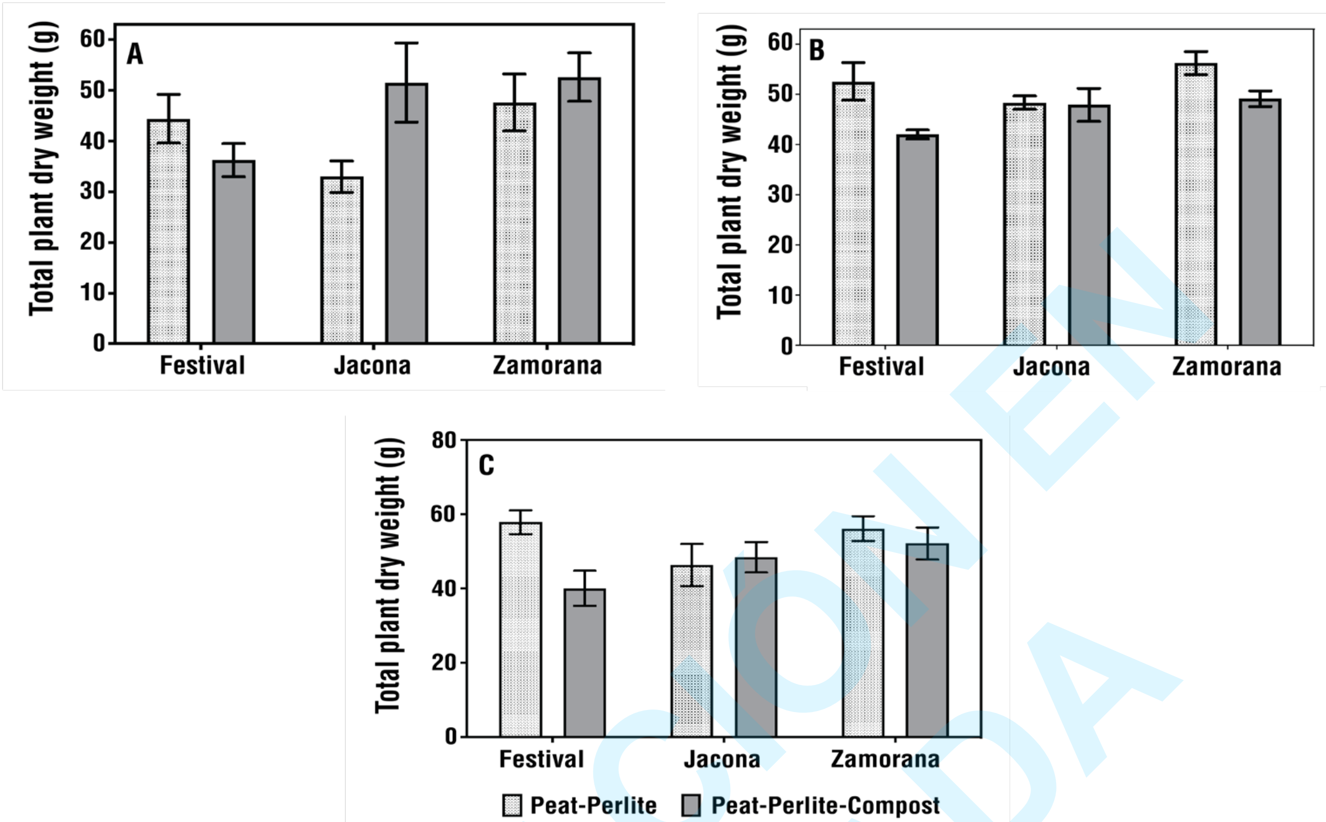

Figure 4. Interaction effects of growing media and cultivar on plant dry weight at November 4 (A), February 13 (B) and April 9 (C). Error bars are standard errors.

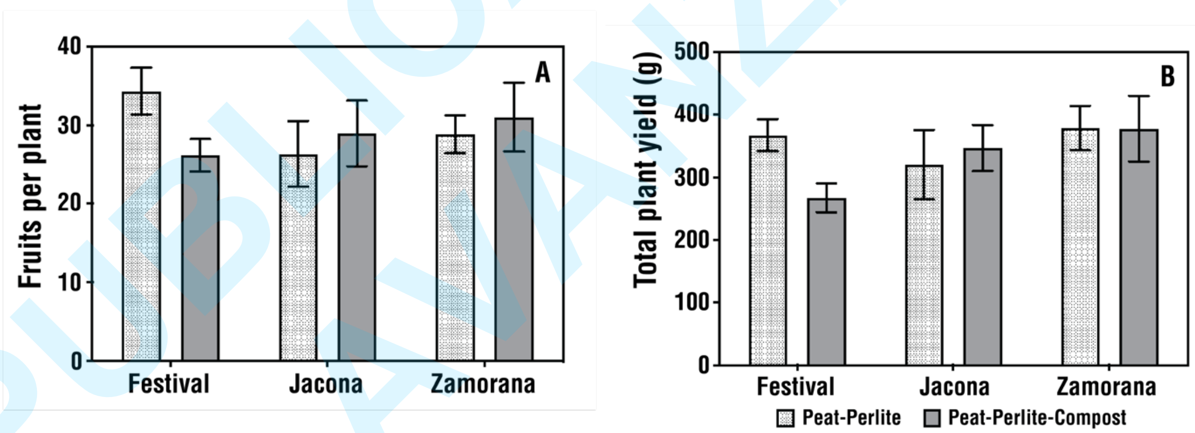

Figure 5. Interaction effects of growing media and cultivar on number of fruit per plant (A) and total plant yield (B). Error bars are standard errors.

roots from plants grown without compost (Figure 1G) which may indicate not only a remobilization of dry matter from these organs to growing fruits, but also a kind of balance among roots, leaves and fruits to maintain fruit development.

Regarding cultivars, 'Zamorana' showed to be more vigorous and high yielding than 'Festival' and 'Jacona'. 'Zamorana' also had bigger fruits during the fruiting period (Tables 1 and 4; Figure 3B). In the case of the interaction effect analysis, Figures 4 and 5 show that 'Festival' was more affected by substrate than 'Jacona' and 'Zamorana', which achieved similar total dry weights, similar fruits per plant, and also similar total plant yields irrespective of the compost in the growing media.

Among the three cultivars, the favorable response of 'Zamorana' in the present work to the pot systems with sheep manure compost made it a suitable cultivar in the region of study for pot production, which should be considered for urban and peri-urban sustainable systems, thus looking for food security in these areas.

Conclusion

Sheep manure compost had no effect on total strawberry yield in the production systems used. Even though SPAD units and dry matter were lower during fruiting in plants grown in compost, leaf physiology was barely affected by treatments. Also, apparently dry matter remobilization, mainly from roots and leaves, could play a key role in fruit development and erase the negative manure effect on plant dry weight during fruiting. Strawberry 'Zamorana' seems like a suitable genotype for pot production with compost-based substrates. Such cultivar behaved favorably in both kinds of substrates studied.

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