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Florida Citrus Nursery Trends and Strategies to Enhance Production of Field-Transplant Ready Citrus Plants

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Abstract: The Florida citrus industry is going through major changes and considerable replanting. Many growers are planting varieties, especially rootstocks, that are potentially productive under Huanglongbing (HLB; *Candidatus* Liberibacter asiaticus) prevalent conditions. However, the high demand for new plant material has put tremendous pressure on citrus nurseries and has created a bottleneck in production. Often it can take more than one year to produce field-transplant ready plants in nurseries; therefore, there is a critical need to accelerate plant production. This three-part study was conducted with the following objectives: (1) determine citrus nursery trends; (2) evaluate use of compost for rootstock germination; and, (3) evaluate use of compost for rootstock seedling growth. According to the nursery survey, rootstock seed germination and seedling growth were the most time-consuming, taking 6–8 months. Moreover, it was apparent from the survey results that 44% of the citrus nurseries were experimenting with potting mixes to achieve adequate plant growth and quality. Our greenhouse study demonstrated successful use of yard waste compost in place of peat moss in a potting mix. With use of 37% to 50% of compost in the potting mix, the overall germination rate and mean emergence time were improved to 70% in less than four weeks for US-897 rootstock as compared to no compost in the potting mix. In addition, 37% to 50% compost resulted in higher biomass accumulation in seedlings. When seedlings of rootstocks C-32 and Flying Dragon were grown with 37% to 50% compost, the growth rate and, therefore, percentage of successful budding were significantly increased as compared to no compost. In addition, substrate analysis indicated that a high compost potting media was rich in mineral nutrients, hence the use of fertilizer in nurseries could be minimized. Altogether, use of compost in place of peat moss seems promising and could accelerate germination and growth of rootstocks, reducing the production time as well as cost.

Keywords: rootstocks; compost; Huanglongbing; germination; potting mix; US-897; C-32; Flying Dragon

1. Introduction

Citrus is one of the largest and most important fruit crops grown in 135 countries and regions around the world. Citrus plants grown commercially are composed of rootstock and scion varieties, and the rootstocks have a great impact on scion growth [1], nutrition [2], fruit size, yield and quality [1,3] as well as to tolerance to biotic and abiotic stresses [4,5]. Therefore, the choice of rootstock can significantly contribute to the success or failure of a planting. Most of the commercially used citrus rootstocks produce nucellar embryos [6,7], allowing the use of seeds for rootstock propagation.

Therefore, citrus nurseries often propagate their own rootstocks and graft the desired scions later, once the rootstock seedling has reached optimum maturity (as per nursery standards).

With the advent of bacterial citrus disease, Huanglongbing (HLB; *Candidatus* Liberibacter asiaticus), also known as citrus greening, the Florida citrus industry including the nurseries have been experiencing many changes and challenges. HLB is a serious citrus disease and threatens citrus production wherever it is present. All citrus species are susceptible to HLB, and currently there is no cure for HLB [8]. HLB causes a severe decline of trees and significant fruit drop, eventually rendering trees unproductive [8–10]. Currently, many growers are relying on good nutritional care of trees [11,12]. However, good nutrition management can be intensive and sometimes unsuccessful [13]. Optimistically, there are some newly introduced citrus rootstocks that exhibit HLB-tolerant characteristics, such as US 941 and US-897 [14,15]. These rootstocks are affected by HLB, however they continue to grow uninterrupted. Under such conditions, many growers are opting for new plantings with potentially HLB-tolerant rootstocks. However, seed availability and the time required to grow seedlings have created a bottleneck. Therefore, citrus nurseries often find themselves in a difficult position in trying to meet clientele demand. Table 1 shows the most propagated rootstocks in Florida according to the annual bud registration report by the Florida Department of Agriculture and Consumer Services (FDACS) [16]. It is apparent that the rootstock trends are currently very dynamic. Currently, Florida citrus nurseries are exploring new propagation methods for citrus rootstocks to overcome the limited seed problem [17], though the production time to produce field-transplant ready plants is still a concern. Therefore, the nurseries are expected to meet clientele demand for these relatively new genotypes in addition to having the capability to grow these new rootstocks as soon as possible to obtain a field-ready transplant. Moreover, since the early 2000s, Florida citrus nurseries are required to conduct 100% indoor production, thereby increasing the production cost of the plants. Therefore, citrus nurseries are actively looking for ways to cut production costs without compromising the quality of the plants produced.

Table 1. Rootstock rankings based on number propagated by the Florida citrus nursery. Data adapted from citrus budwood report 2015-2016 [16].

Rank	2016	2015	2014	2013	2012
1	Kuharske	Kuharske	Swingle	Swingle	Swingle
2	X-639	X-639	Kuharske	Sour Orange	Kuharske
3	Sour Orange	Swingle	Sour Orange	Kuharske	Sour Orange
4	US-897	Sour Orange	X-639	Carrizo	Carrizo
5	Swingle	Cleopatra	US-802	US-812	X-639
6	US-942	US-802	US-812	X-639	Volkamer
7	US-802	US-897	US-897	US-897	Cleopatra
8	US-812	US-942	Cleopatra	Cleopatra	US-802
9	Cleopatra	US-812	Carrizo	US-802	US-812
10	UFR-04	C-35 Citrange	Volkamer	Volkamer	Kinkoji

Generally, in covered and containerized nurseries such as citrus in Florida, potting mixes are used and often some portion of it is composed of peat moss [18,19], although the use of potting mix can be fairly expensive and add to the production cost. Peat moss is a natural, organic soil conditioner, regulating moisture and air around plant roots for ideal growing conditions. However, peat moss is expensive [20,21], and therefore the use of an alternative would be beneficial [21,22]. Previous work has shown that compost can be used for citrus rootstock germination [23] or production [24] and the low cost of compost could reduce production costs [19–21,25]. Bunt [19] reported that the use of up to 30% compost in potting media is optimal and yields acceptable results. Stoffella et al. [23] reported the successful use of sugarcane compost as potting media for sour orange and Cleopatra mandarin rootstock germination. They also reported that 100% sugarcane compost germination media reduced germination rate as compared to 25% to 75% media. It should be noted that this work was limited to sugarcane compost and that the rootstocks used were vigorous [1]. Currently, the most popular citrus rootstocks in Florida are trifoliate hybrids [16], which are generally low vigor and can take more time to grow, especially in fall and winter [1,26]. Therefore, it is critical to identify strategies to optimally grow these relatively new rootstocks without adding more production time and cost.

This study was conducted with three objectives: (1) determine Florida nursery trends; (2) evaluate the use of compost for rootstock germination; and, (3) evaluate the use of compost for rootstock seedling growth. The rootstock US-897 (Cleopatra mandarin (*Citrus reticulata* Blanco) × Flying Dragon trifoliate orange (*Poncirus trifoliata* (L.) Raf.)) was used in the germination study because of its high demand by citrus growers due to potential HLB tolerance [14]; Flying Dragon (*Poncirus trifoliata* (L.) Raf.) and C-32 (F1 hybrid between 'Ruby' orange (CRC 589) and 'Webber-Fawcett' trifoliate (CRC 2552)) were used in the seedling growth study as the effect of the treatments would likely be more apparent due to their slow growth characteristics and be useful for the industry with similar slow-growing rootstocks as compared to vigorous rootstocks [1,26,27].

2. Materials and Methods

2.1. Nursery Production Survey

A question-based survey of the Florida citrus nursery was conducted in 2016. To have maximum feedback, the citrus nurseries were reached by mail survey as well as online survey. The questions in the survey were related to germination and growing media, time taken in production, and fertilizer regimes.

2.2. Greenhouse Experiment

The greenhouse experiment consisted of two separate experiments that were repeated twice in same year: (1) rootstock seed germination; (2) rootstock seedling growth and budding. The study was conducted in a greenhouse at the Citrus Research and Education Center, Lake Alfred, Florida, during the months of April to November in 2016 under natural light conditions. The temperature and relative humidity of the greenhouse fluctuated between 22 °C to 25 °C and 60% to 80%, respectively. The experiment was set up as a completely randomized design with 5 compost-potting media treatments (Table 2). The seeds for both experiments were purchased from Lyn Citrus Seed, Inc. (Bakersfield, CA, USA). The seeds were collected from the mother rootstock trees in 2016. Once the seeds were received, they were stored in the dark in a refrigerator and were not treated with fungicide or any other chemical.

Table 2. Potting medium composition of five different potting media prepared for citrus rootstock germination and seedling growth.

Treatments	Peat Moss (%)	Perlite (%)	Vermiculite (%)	Compost (%)
T1	50	40	10	0
T2	37.5	40	10	12.5
T3	25	40	10	25
T4	12.5	40	10	37.5
T5	0	40	10	50

2.2.1. Potting Media and Analysis

Based on the survey results, potting media (T1) were prepared to resemble a commercial potting mix. The commercial potting mix Fafard® germination mix is primarily composed of Canadian sphagnum peat moss, perlite, and vermiculite; T2–T5 were different potting media where a certain percentage of peat moss was replaced by compost. The compost used in this study was a yard waste (mostly shrubs and grass trimmings), composted under controlled conditions. The same media were used for seed germination and seedling growth. Table 2 shows the potting media treatment ingredients and ratios. Briefly, compost, peat moss, perlite, and vermiculite were mixed homogenously at different ratios (w/w basis) and used as the potting media. The perlite and vermiculite were kept at a constant ratio in the 5 different potting media and the ratio of compost and peat moss ranged from 0–50% in the different media. Electrical conductivity (EC), pH, nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), sulfur (S), boron (B), zinc (Zn), manganese (Mn), iron (Fe) and copper (Cu) in the potting media were analyzed by a commercial nutrient testing lab (Waters Lab, GA) and the organic matter (OM) content was measured by loss on ignition (Table 3).

Table 3. Physical and chemical characteristics of five different potting media used for germination of citrus and growing citrus C-32 and Flying Dragon, respectively. T 1 (peat moss + perlite + vermiculite + compost at 50:40:10:0 (w/w)), T 2 (peat moss + perlite + vermiculite + compost at 37.5:40:10:12.5 (w/w)), T 3 (peat moss + perlite + vermiculite + compost at 25:40:10:25 (w/w)), T 4 (peat moss + perlite + vermiculite + compost at 12.5:40:10:37.5 (w/w)), T 5 (peat moss + perlite + vermiculite + compost at 0:40:10:50 (w/w)). Means followed by different letters are statistically different from each other by Tukey's honest significance difference at $\alpha = 0.05$, or not significantly different (*ns*). EC = electrical conductivity; OM = organic matter.

Characteristic	T1	T2	T3	T4	T5	*p*-Value
pH	6.0	5.9	6.1	6.4	6.7	*ns*
EC (dSm-2)	0.56 c	1.25 bc	2.13 bc	2.91 b	4.06 a	<0.001
OM (%)	34.6 ab	39.0 a	33.1 b	32.3 b	28.5 c	*ns*
N (ppm)	39.55 c	45.15 c	78.75 b	75.25 b	112.70 a	<0.001
P (ppm)	3.70 c	20.78 a	19.73 a	20.25 a	9.57 b	0.032
K (ppm)	10.1 e	48.3 d	102.1 c	175.6 b	252.7 a	<0.001
Mg (ppm)	5.66 c	17.82 c	34.94 bc	44.41 b	61.58 a	0.027
Ca (ppm)	12.63 d	30.00 c	58.78 bc	79.16 b	121.40 a	0.012
S (ppm)	39.02 d	61.12 cd	85.84 bc	107.10 b	147.80 a	0.006
B (ppm)	0.14 d	0.33 c	0.48 bc	0.58 b	0.88 a	0.034
Zn (ppm)	0.02	0.06	0.03	0.03	0.05	*ns*
Mn (ppm)	0.03	0.07	0.09	0.07	0.03	*ns*
Fe (ppm)	0.17	0.4	0.13	0.26	0.02	*ns*
Cu (ppm)	0.01	0.02	0.03	0.04	0.03	*ns*

2.2.2. Germination Evaluation

Citrus rootstock seeds of US-897 (Cleopatra mandarin (*Citrus reticulata* Blanco) × Flying Dragon trifoliate orange (*Poncirus trifoliata* (L.) Raf.)) were hand sown in treatment media in 'Nu Pots square', 8 cm × 8 cm, (Hummert International, Earth City, MO, USA) containers with a total volume of 512 cm^3 (8 seeds per container). The pots were arranged in blocks in trays; at least 6 seeds were considered as one replicate, and there was a total of 6 replicates per treatment. Sown seeds were watered until runoff once a day with a spray bottle until the day of emergence, and then they were watered with 20 mL twice every day. No fertilizer was added to the pots. Germination data was collected up to 9 weeks after sowing, and mean emergence time and germination percent were calculated according to the equations by Ranal and De Santana [28]. Germinated seedlings were evaluated for true-to-type appearance, and any seedlings that appeared to be a result of sexual fertilization were removed. In order to have at least 6 seedlings per replicate, 8 seeds were sown for each replicate. Data on seedling height, stem diameter and number of leaves were collected every week from the date of seed germination until 10 weeks. Height of the seedlings was measured from the media surface to the tip of the seedling, while stem diameter was measured with a caliper 2 cm above the media surface. The number of mature leaves was counted starting from the base of the stem. Seedlings were harvested at the end of the experiment, and separated into roots, shoots, and leaves. Fresh weights of roots, shoots, and leaves of each seedling were measured, then all seedling tissues were dried in a forced draft oven at 70 °C for 72 h to a constant weight and measured for dry weight.

2.2.3. Seedling Growth and Budding Evaluation

Approximately 10 week old seedlings (true-to-type) of C-32 citrange (F1 hybrid between 'Ruby' orange (CRC 589) and 'Webber-Fawcett' trifoliate (CRC 2552)) and Flying Dragon (*Poncirus trifoliata* (L.) Raf.) grown under the same initial conditions were transferred to containers with potting media treatments. The experiment was set up as a completely randomized block design, with 4 replicates of 3 seedlings per replicate. The containers used were 'Ray leach Cone-tainers', SC-10 (Stuewe and Sons, Inc., Corvallis, OR, USA), with a 3.8 cm diameter × 21 cm depth and 238 cm^3 volume. Seedlings were irrigated with 50 mL water by hand every other day, and no fertilizer was added to the growing mix. Data on seedling height, stem diameter and number of leaves were collected every week until 10 weeks. Height of the seedlings was measured from the media surface to the tip of the seedling, while stem diameter was measured with a caliper 2 cm above the media surface. The number of mature leaves was counted starting from the stem base. After 10 weeks, the rootstock seedlings from all treatments were grafted using healthy buds of sweet orange cultivar, Valencia, via 'T budding', using two buds per seedling about 10–20 cm from the soil line. The grafts were covered with grafting tape for 3 weeks. Then, the plants were evaluated for the success of budding.

2.3. Statistical Analyses

Both the germination and seedling growth experiments were repeated twice, and results from the two separate experiments were statistically similar. Therefore, data were pooled and analyzed together for treatment means. Statistical analyses of the data were performed using one-way analysis of variance (ANOVA) with SigmaPlot (version 11; Systat Software, San Jose, CA, USA). Mean separation was performed using Tukey's honest significance difference (HSD) test at $\alpha = 0.05$.

3. Results and Discussion

3.1. Nursery Production Survey

In 2016, there were 54 active nurseries reported in Florida [16]. All the nurseries were contacted for the survey, and the survey was conducted via two outreach methods: mail and online. Overall, 15 out of 54 nurseries responded to the survey. However, as indicated in the survey response, these 15 nurseries were responsible for approximately 1.9 million propagated rootstocks in 2015–2016 which is roughly 45% of total nursery production reported in 2015–2016 [16]. The majority of the participating nurseries reported more than 100,000 propagated trees produced each year, which is higher than the average number of propagated per nursery as reported by FDACS [16].

With regards to fertilizer, the majorty of the nurseries used controlled-release fertilizers for seed and seedling growth with only one nursery using fertigation.

Participating nurseries reported that their rootstock germination success rate varied from 60–95%, where the most common response was 80–90% and the germination time ranged from 3–6 weeks. Both parameters were dependent on the rootstock and season, where spring and summer were more favorable for germination whereas late fall and winter slowed down the process. With regards to germination media, there were five types of germination mixes reported by the participants (Figure 1); Fafard® germination mix was the most popular and 50% of the participating nurseries used it for rootstock seed germination. Interestingly, 25% of the nurseries reported using their own custom blends for a germination mix which mostly included blends of peat moss, perlite, and coconut coir in some cases. The approximate number of propagations made by the nurseries using custom blends were 750,000 compared to 662,000 propagations made by nurseries using Fafard® germination mix, suggesting that the nurseries using custom blends were large-scale nurseries and likely had the infrastructure and resources to make their own blends.

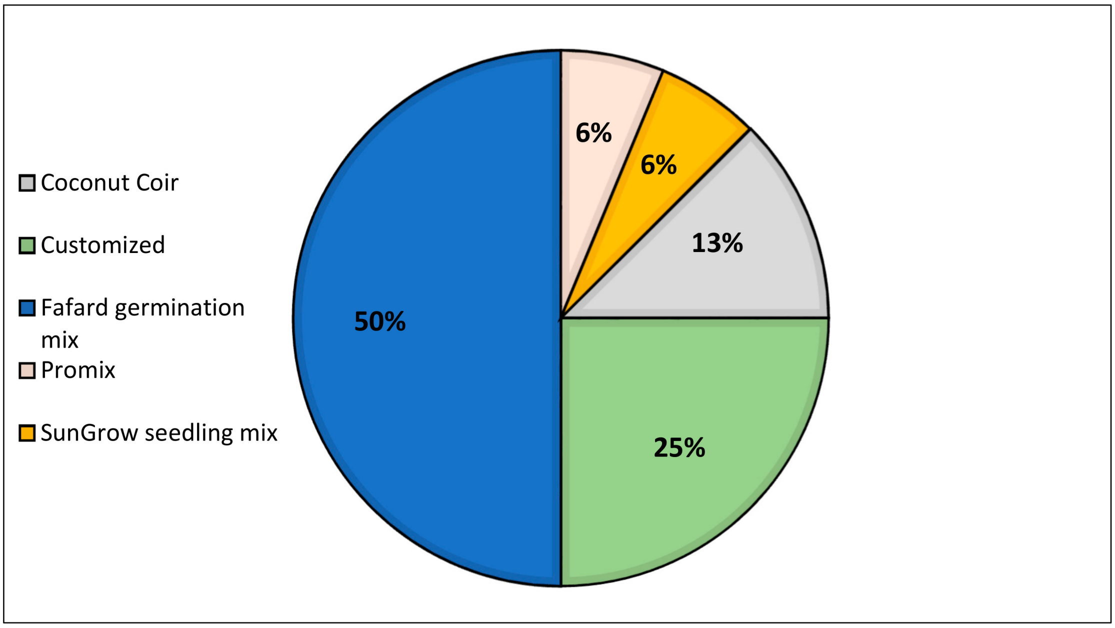

Figure 1. Survey results of the use of different types of germination media for citrus rootstock seed by Florida citrus nurseries.

Nurseries were also asked about production practices for the rootstock seedlings, including time of transfer from germination to liner growth and time before successful budding. Overall, it was reported that it takes about 3–6 months from the time of germination to first rootstock seedling (liner) transfer to a growing media and within 2–4 months of transfer, the seedling is budded. Forty-four percent of the nurseries (representing 680,000 propagations) reported using customized growing media, which was always comprised of a blend of peat moss and perlite. Some of the other ingredients of custom blends were nursery specific and included pine bark, sand, and wood chips. Following custom blends were Fafard® germination mix and coconut coir (Figure 2) as the most used potting mixes.

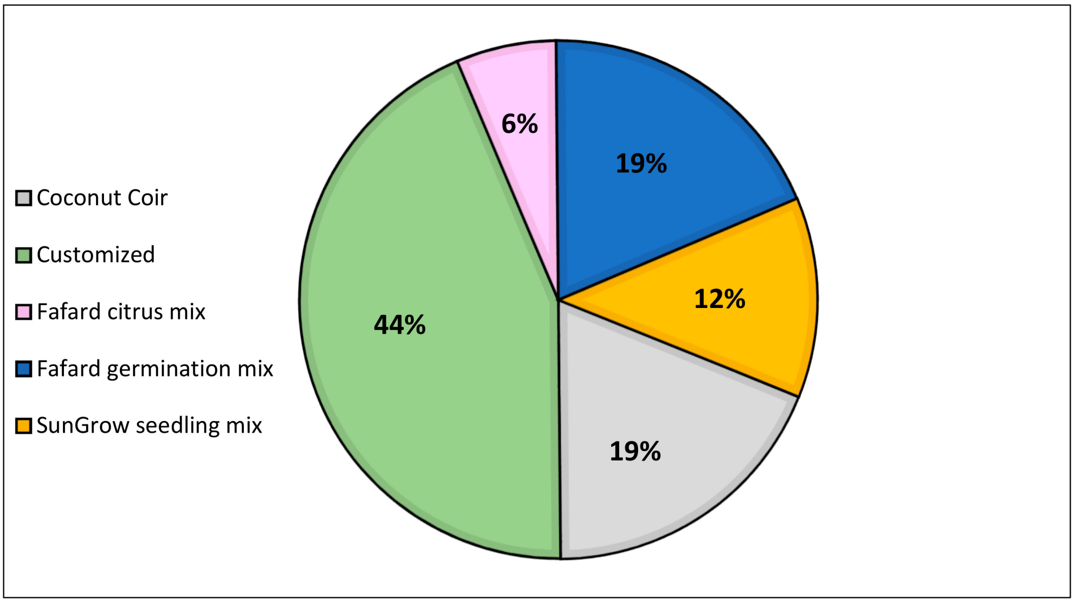

Figure 2. Survey results on use of different types of growing media for citrus rootstocks (liners) by Florida citrus nurseries.

3.2. Greenhouse Experiment

3.2.1. Potting Media Analysis

Physical and chemical analysis of the five potting media treatments used in this study are provided in Table 3. T5 (potting media with highest compost percentage) had the highest electrical conductivity as compared to T1 (potting media with no compost), which was approximately seven times lower than that of T5, the other treatments were intermediate. It was interesting to note that organic matter in T2 was significantly higher than all the treatments whereas T1, T3, and T4 had similar organic matter, although they differed significantly in their compost or peat moss content. The treatment with the highest compost (T5) had significantly lower organic matter content, suggesting yard waste compost is not a rich source of organic matter as compared to peat moss. However, a blend with a high percentage of peat moss and low percentage of compost can generate a mix with high organic matter by complementing each other, whereas a blend with no compost (T 1) or high percentage of compost (T3, T4, and T5) remained low in organic matter. Upon mineral nutrient analysis, it was revealed that T5 had significantly higher levels of nitrogen, potassium, magnesium, calcium, sulfur, and boron as compared to T1. The level of phosphorus, zinc, manganese, and copper were somewhat variable in the different potting media although they were not significantly different. Interestingly, T5 had the highest pH as compared to T1 and T2. These physical and chemical properties are in agreement with the literature where compost made from vegetable waste [29], almond shells [30], yard waste [21], and sugarcane waste compost [23] have had high EC and soil pH. Overall, the source of compost may differ but, generally, compost originating from plant waste tends to have high mineral nutrient and EC properties [25,29].

3.2.2. Germination Evaluation

The maximum germination rate for US-897 seeds was approximately 70% by eight weeks after sowing (Figure 3). A significant ($p < 0.001$) effect of potting media on germination rate was observed, where the potting media with the highest compost percentage (T5) had the highest germination rate. The germination rate was directly related to the compost percentage in the potting mixes as indicated by correlation analysis ($p < 0.001$; $R^2 = 0.68$). In addition, the mean emergence time was also dependent on the compost content of potting media, where T5 and T4 had the most accelerated germination as compared to other treatments and reached the germination rate plateau by the seventh week of evaluation. Figure 4 shows the mean emergence time of the seeds in each potting media; T5 and T4 had an average time of approximately four weeks, whereas T1 (no compost) had the longest emergence time of approximately six weeks ($p < 0.01$). Figure 5 shows pictures of rootstock seedlings at the end of nine weeks of germination. It is evident from the picture that due to early germination in the high compost media treatments, the seedlings had more growth at nine weeks. This visual observation was also supported by the plant biomass data, where T5 and T4 had a significantly ($p < 0.001$) higher total biomass of 0.59 g and 0.42 g, respectively, as compared to T1, T2, and T3 (Figure 6). Similarly, root and leaf, but not shoot, tissues showed the same pattern as total biomass. Stoffella et al. [23] reported that use of sugarcane compost ranging from 25% to 75% had a germination rate and mean emergence time similar to peat-lite potting mix. Our results indicated that yard compost may have more beneficial properties compared to sugarcane compost; nonetheless, compost can be successfully used to substitute for peat moss in the potting mix, thereby providing an environmentally and economically friendly alternative.

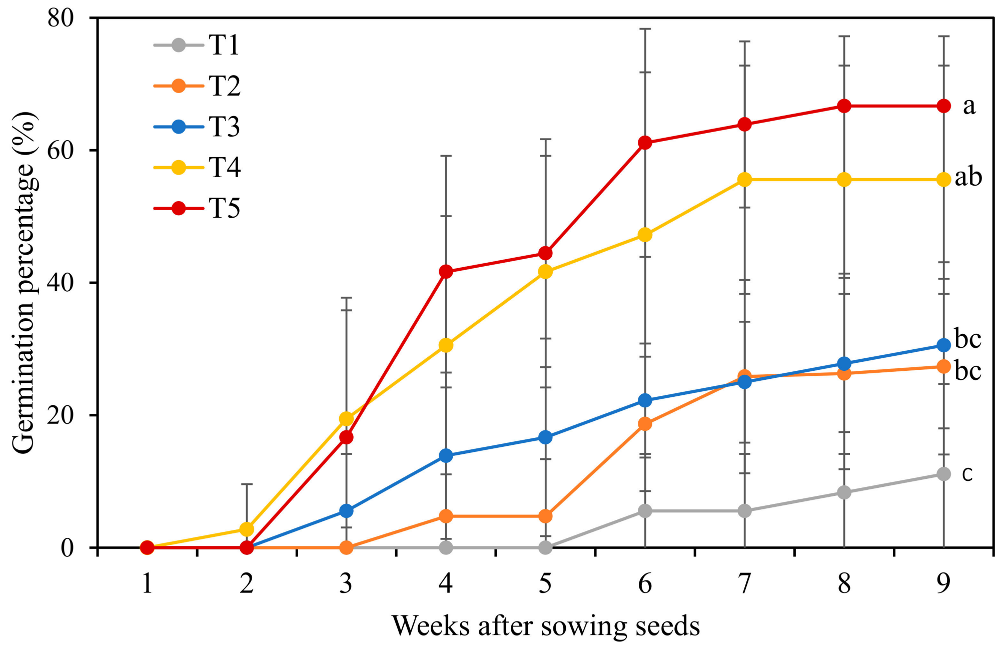

Figure 3. Average weekly germination rate (%) of citrus rootstock US-897 sown in five different germination media. Each mean is shown with its standard deviation. Media: T1 (peat moss + perlite + vermiculite + compost at 50:40:10:0), T2 (peat moss + perlite + vermiculite + compost at 37.5:40:10:12.5), T3 (peat moss + perlite + vermiculite + compost at 25:40:10:25), T4 (peat moss + perlite + vermiculite + compost at 12.5:40:10:37.5), T5 (peat moss + perlite + vermiculite + compost at 0:40:10:50). Means at nine weeks followed by different letters are statistically different from each other by Tukey's honest significance difference at $\alpha = 0.05$.

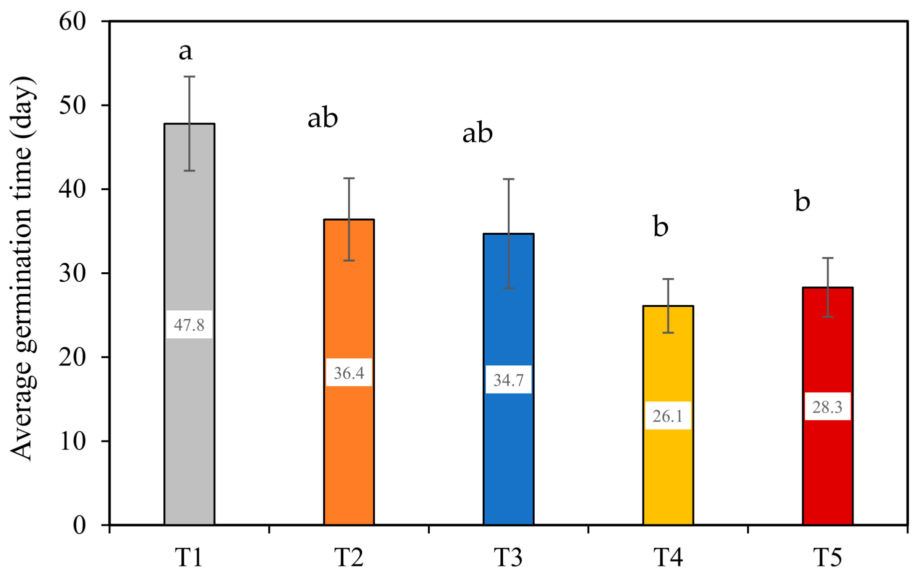

Figure 4. Average germination/emergence time days ± standard deviation for citrus rootstock US-897 sown in five different germination media: T1 (peat moss + perlite + vermiculite + compost in ratio 50:40:10:0), T2 (peat moss + perlite + vermiculite + compost in ratio 37.5:40:10:12.5), T3 (peat moss + perlite + vermiculite + compost in ratio 25:40:10:25), T4 (peat moss + perlite + vermiculite + compost in ratio 12.5:40:10:37.5), T5 (peat moss + perlite + vermiculite + compost in ratio 0:40:10:50). Bars (mean ± standard deviation) with different letters are statistically different by from each other by Tukey's honest significance difference at $\alpha = 0.05$.

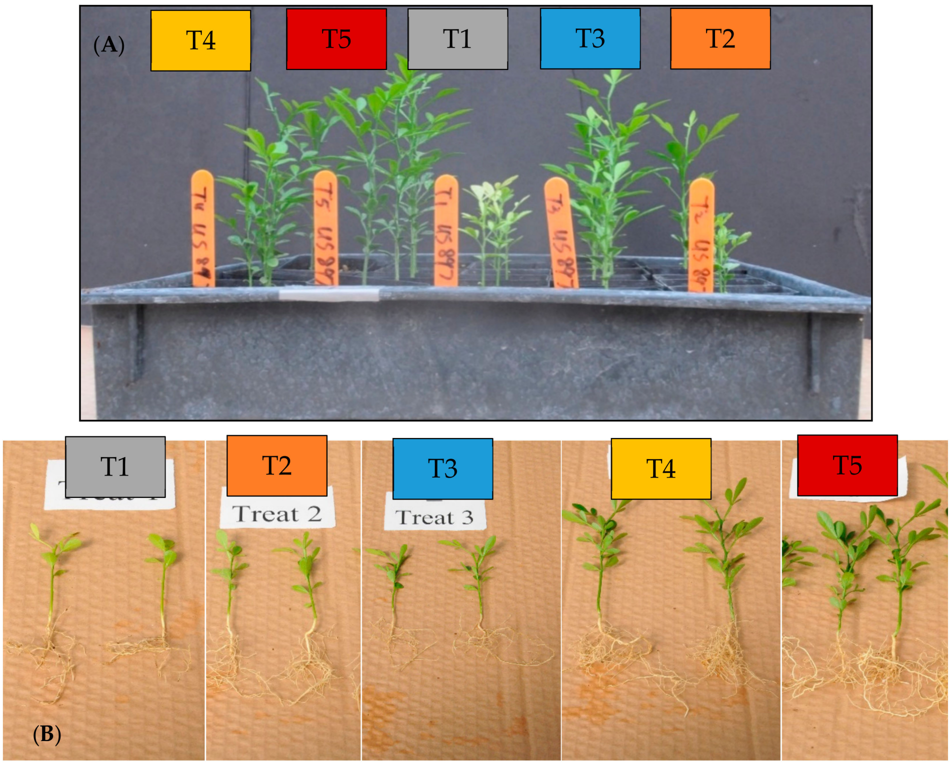

Figure 5. Picture showing germinated plants of US-897 citrus rootstock (**A**) and seedlings with roots (**B**) US-897 after nine weeks in five different germination media: T1 (peat moss + perlite + vermiculite + compost at 50:40:10:0), T2 (peat moss + perlite + vermiculite + compost at 37.5:40:10:12.5), T3 (peat moss + perlite + vermiculite + compost at 25:40:10:25), T4 (peat moss + perlite + vermiculite + compost at 12.5:40:10:37.5), T5 (peat moss + perlite + vermiculite + compost at 0:40:10:50).

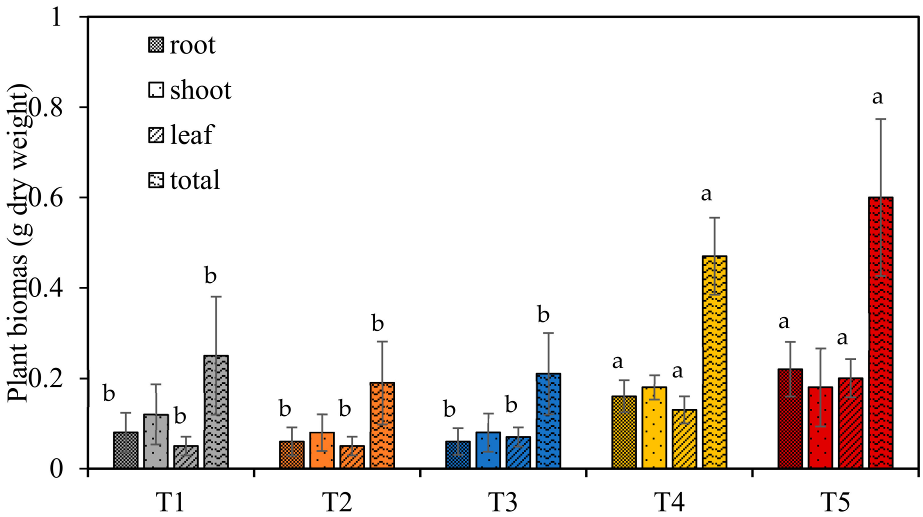

Figure 6. Average root, shoot, leaf and total biomass (g) ± standard deviation of citrus rootstock US-897 at nine weeks in five different germination media: T1 (peat moss + perlite + vermiculite + compost at 50:40:10:0), T2 (peat moss + perlite + vermiculite + compost at 37.5:40:10:12.5), T3 (peat moss + perlite + vermiculite + compost at 25:40:10:25), T4 (peat moss + perlite + vermiculite + compost at 12.5:40:10:37.5), T5 (peat moss + perlite + vermiculite + compost at 0:40:10:50). Bars (mean ± standard deviation) within tissue types with different letters are statistically different from each other by Tukey's honest significance difference at $\alpha = 0.05$. No letter for shoots indicates no significant differences.

3.2.3. Seedling Growth and Budding Evaluation

To evaluate the effect of growing media on the growth of seedlings, 10-week-old seedlings, previously germinated and grown under the same conditions, were used. Two rootstock varieties, C-32 and Flying Dragon, were grown in the five different potting media for 10 weeks before budding them with a scion. Figure 7 shows the average increase in height, trunk diameter and leaf number for both rootstocks at 10 weeks of growth in the five different potting media. All the seedlings used in the experiment started with a similar height, trunk diameter, and leaf number in order to allow potting media effects on growth to become apparent (Figure 7). Overall, both rootstock cultivars showed similar growth responses, and no prominent genotype effect was observed. T5 and T4 (i.e., potting media with high compost ratios) showed a significantly greater height ($p < 0.001$) compared to T1 (i.e., potting media with no compost). The increase in C-32 trunk diameter was significantly higher in T5 as compared to T1, whereas all the other treatments were intermediate; on the other hand, T5, T4, and T3 showed the greatest increase in trunk diameter of Flying Dragon, whereas T1 and T2 were significantly lower. Interestingly, no significant effect of potting media was observed on leaf number for either varieties. However, a consistent increase in leaf number with an increase in the ratio of compost in potting media was revealed by correlation analysis ($p < 0.001$; $R^2 = 0.59$). Overall, increase in the amount of compost in the potting media visually increased seedling growth (Figure 8). The rootstock seedlings/liners that were grown in the respective growing media were budded with scions after 10 weeks (Figure 9). There was 83% successful budding of Flying Dragon in T5 as compared to 58% in T1, which was significantly ($p = 0.02$) lower than T5 and T4, while other treatments were intermediate. For C-32 rootstock, T4 and T5 had 75% and 67% successful budding, respectively, as compared to 62% in T1, however, they were not statistically different ($p = 0.125$). Altogether, a trend of more successful budding with a higher compost treatment was observed, which was possibly due to advancement in growth in those treatments increasing the acceptance/survival of the grafted buds. Similar results of good growth characteristics or no negative effects with use of compost have been reported in tomato [21], melon [29], wheat [31], and grape [32]. In all of these studies, the use of compost resulted in comparable growth results when compared with potting mixes and regularly used substrates. It should be noted that in the present study, enhanced growth characteristics with use of compost as compared to the no compost media were observed. We propose that a high nutrient profile, especially of nitrogen (Table 2) [25,29,31–33], in high compost treatments resulted in enhanced growth. Many studies of citrus seedlings [34–36] have demonstrated that rapid growth of the shoot is dependent on and supported by nitrogen availability in containerized citrus plants. Hence, with the use of compost, fertilizer application could be reduced, thereby saving money and resources spent on fertilizer application. For the future, an economic analysis evaluating the use of compost in place of peat moss, the reduced use of fertilizer application, and the effects of improved growth (and a potentially high turnover in the same time) would be beneficial.

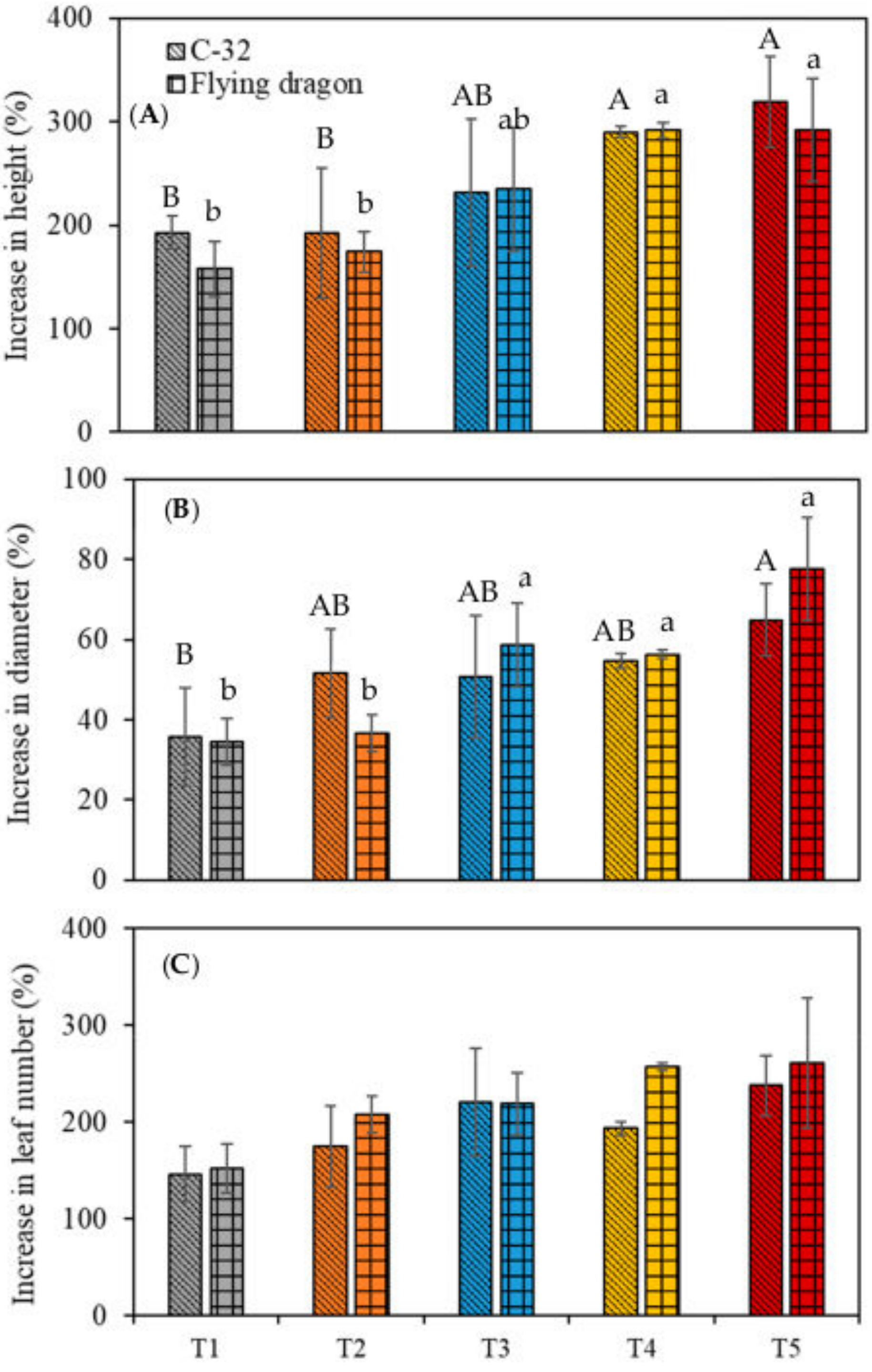

Figure 7. Average increase in height (**A**), trunk diameter (**B**), and leaf number (**C**) of citrus rootstock C-32 and Flying Dragon seedlings at 10 weeks when grown in five different germination media: T1 (peat moss + perlite + vermiculite + compost at 50:40:10:0), T2 (peat moss + perlite + vermiculite + compost at 37.5:40:10:12.5), T3 (peat moss + perlite + vermiculite + compost at 25:40:10:25), T4 (peat moss + perlite + vermiculite + compost at 12.5:40:10:37.5), T5 (peat moss + perlite + vermiculite + compost at 0:40:10:50). Bars (mean ± standard deviation) within rootstocks with different letters are statistically different from each other by Tukey's honest significance difference at $\alpha = 0.05$, with uppercase letters for rootstock C-32 and lowercase letters for Flying Dragon.

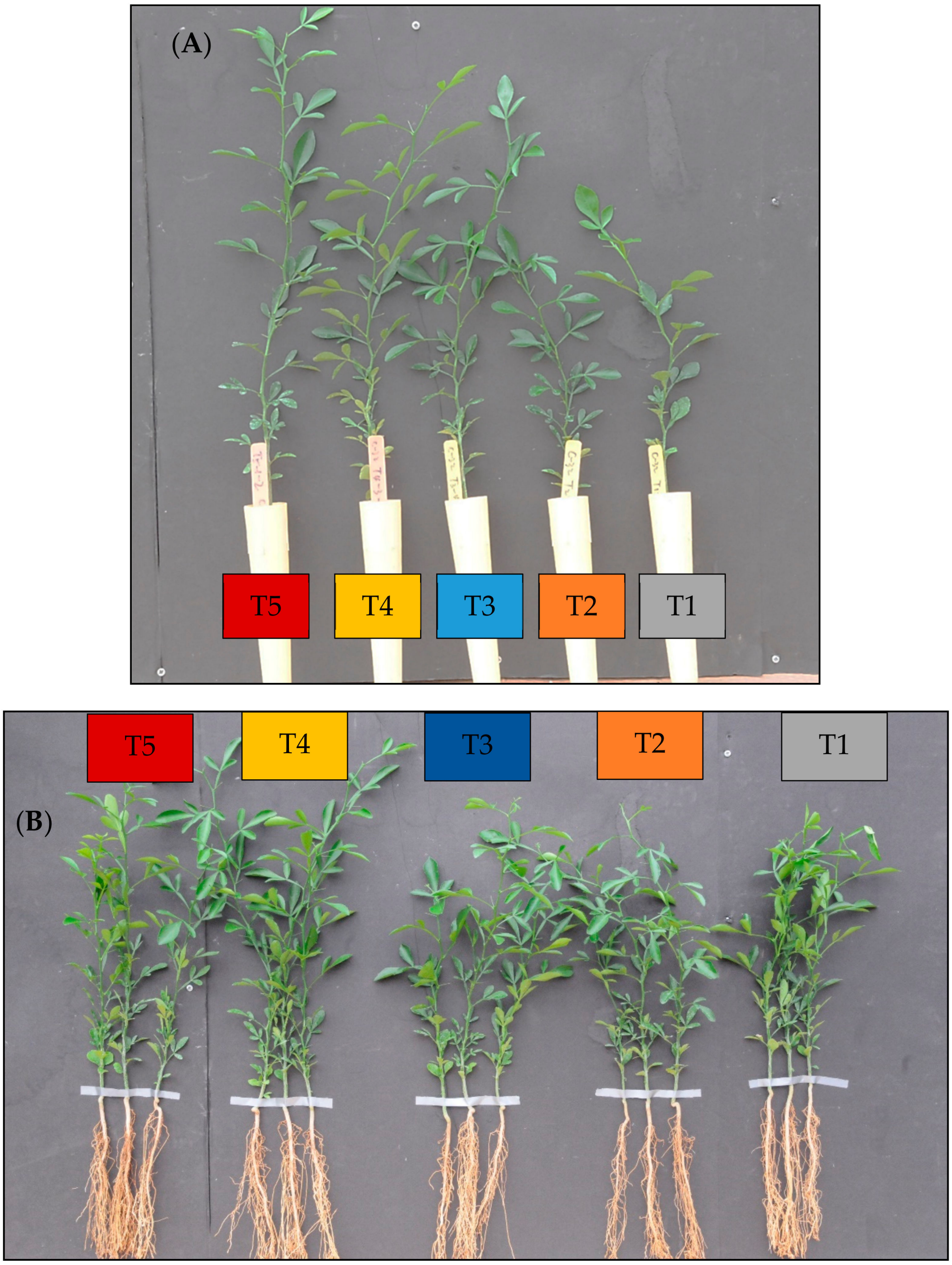

Figure 8. Picture showing growing seedlings (**A**) and (**B**) of citrus rootstock Flying Dragon after 10 weeks in five different growing media: T1 (peat moss + perlite + vermiculite + compost at 50:40:10:0), T2 (peat moss + perlite + vermiculite + compost at 37.5:40:10:12.5), T3 (peat moss + perlite + vermiculite + compost at 25:40:10:25), T4 (peat moss + perlite + vermiculite + compost at 12.5:40:10:37.5), T5 (peat moss + perlite + vermiculite + compost at 0:40:10:50).

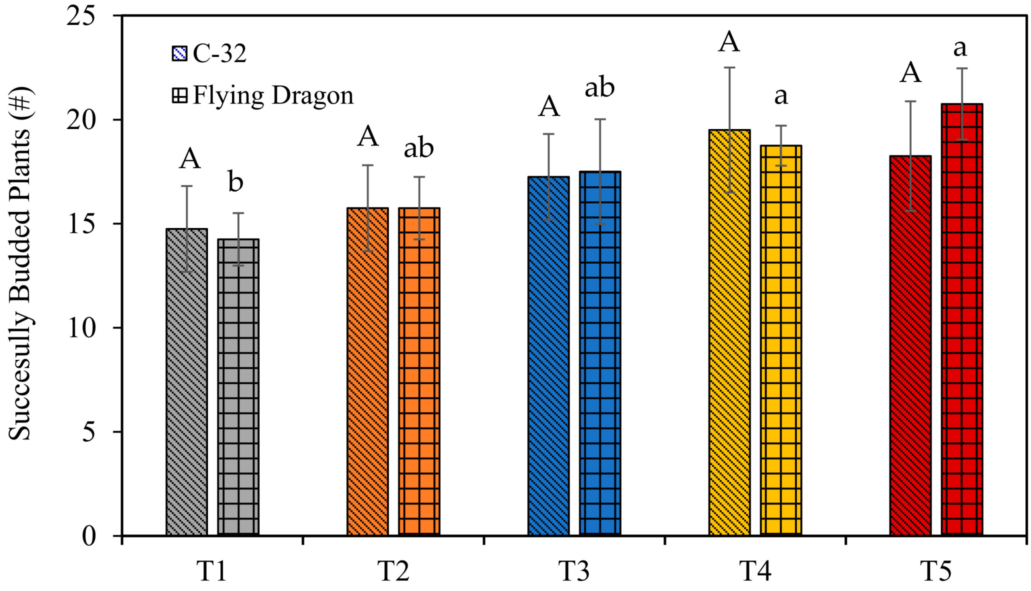

Figure 9. Success of budding of citrus rootstock Flying Dragon and C-32 with 'Valencia' sweet orange buds after growing for 10 weeks in five different growing media: T1 (peat moss + perlite + vermiculite + compost at 50:40:10:0), T2 (peat moss + perlite + vermiculite + compost at 37.5:40:10:12.5), T3 (peat moss + perlite + vermiculite + compost at 25:40:10:25), T4 (peat moss + perlite + vermiculite + compost at 12.5:40:10:37.5), T5 (peat moss + perlite + vermiculite + compost at 0:40:10:50). Bars (mean ± standard deviation) with different letters are statistically different from each other by Tukey's honest significance difference at α = 0.05, with uppercase letters for C-32 and lowercase letters for Flying Dragon.

4. Conclusions

With the advent of HLB, the Florida citrus industry is going through a number of changes in its choice of rootstocks for new plantings, with potentially HLB-tolerant rootstocks being the current favorite choice. Overall, the nursery survey found trends among Florida citrus nurseries. On average, it takes about 6–8 months for the nurseries to prepare rootstock liners to bud from the time of rootstock seed sowing. Following budding, it takes another 2–4 months to get adequate scion growth for a composite plant that is ready for transfer to the field. Altogether, this whole process can take up to 12 months and has become a bottleneck when the demand is high for plants. On the other hand, citrus growers need to assess their needs in advance and may have to wait for a year (if not more) to initiate new plantings. Therefore, due to this time-consuming process of producing citrus trees that are ready for transplant, citrus nurseries find themselves in a stressful situation of producing high quality plants in an accelerated time frame to meet demand and keep their businesses profitable. A number of nurserymen in the Florida citrus industry have been experimenting with germination and potting media mixes, and a significant number of them are using their own custom blends. The custom blend recipes were nursery-specific but a majority of them included peat moss, perlite, and vermiculite. Fafard® germination mix was also reported to be a popular potting mix for rootstock seed germination as well as growth. Nonetheless, whether the potting mix was a custom blend or premade, peat moss was a significant ingredient.

The present study demonstrated that yard waste compost can be used to completely replace peat moss. Moreover, with the use of compost, germination rate, mean emergence time, growth rate, and budding success improved. Therefore, production time may be reduced significantly for production of field transplant-ready trees without compromising the quality of the trees as well as increasing resource input. Moreover, use of compost as well as reduction in the use of fertilizer can be environmentally and economically beneficial.

Author Contributions: T.V. was responsible for the surveys, ideas and intellectuallu input for the study, data analysis and interoperation, and writing in addition to acquiring funds. C.C. was responsible for experimental design, experiment execution, data collection and analysis. M.O.H. provided intellectual input in survey and formulating the study, provided compost, helped with organic matter analysis. M.O.H. also helped with data interpretation. All authors have read and agreed to the published version of the manuscript.

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