Container production of four sweet chili pepper (*Capsicum chinense* Jacq.) lines using soilless substrates[1,2]

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ABSTRACT

Sweet chili pepper (*Capsicum chinense* Jacq.) is an important part of the local cuisine of Puerto Rico where it is known as *ají dulce*. Considering opportunities for vegetable production in Puerto Rico, soilless alternatives for production of sweet chili pepper should be considered. This study evaluated five substrates: (1) PRO-MIX® BX (BX); (2) PRO-MIX® BX + Mycorrhizae (BX+Myco); (3) PRO-MIX® High porosity + Mycorrhizae (HP+Myco); (4) PRO-MIX® High porosity + Mycorrhizae + Biofungicide (HP+Myco+Fung); and (5) coconut coir. Four experimental lines of sweet chili pepper (G-2, Sel-7, G-11 and G-8, to be released as 'Amanecer', 'Bonanza', 'Carnaval', and 'Pasión', respectively) were tested with each substrate. Two outdoor plantings in containers were carried out with a factorial combination of four lines by five substrates: Trial 1 from March to September 2017 and Trial 2 from October 2017 to April 2018. In addition, the four experimental lines were transplanted to the field (Field Control Trial). All plantings took place in Mayagüez, Puerto Rico. Differences among substrates were relatively consistent in Trial 1 and Trial 2. Sweet chili pepper in BX+Myco and HP+Myco+Fung flowered 50.3 days after transplanting (DAT) while plants in coconut coir flowered about two and a half weeks later. There were few or no differences in BX, BX+Myco and HP+Myco+Fung for plant height, number of fruit and total fruit weight. Plants grown in HP+Myco and coconut coir were shorter, with fewer fruits and lower fruit weight. Average fruit weight was similar among all substrates. Relative differences among lines in the three trials were less consistent than for substrates. Line G-11 was the earliest flowering line at 50.1 DAT as well as the shortest line. The other lines flowered eight to 10 days later. The tallest line varied from trial to trial. Line Sel-7 produced the greatest number of fruits per plant in Trial 1 and in the Field Trial, while G-2 and G-8 produced the greatest number in Trial 2. Line Sel-7 had the highest total fruit weight per plant in Trial 1 and in the Field Trial while G-2 had

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the greatest total weight in Trial 2. Despite the high number of fruits in plants of G-8, yields were 60% less because of small average fruit weight. Line Sel-7 had the greatest average fruit weight in Trial 1 while G-11 had the highest fruit weight in Trial 2. This research suggests that, based on its lower cost, BX would be a good choice for soilless production of sweet chili pepper. For production in containers, sweet chili pepper lines G-2 and Sel-7 showed better performance than G-8 and G-11.

Key words: ají dulce, Habanero-type pepper, coconut coir, mycorrhizae, biofungicide

RESUMEN

Producción en tiestos de cuatro líneas de ají dulce (*Capsicum chinense* Jacq.) usando sustratos sin suelo

El ají dulce (*Capsicum chinense* Jacq.) es un componente importante en la cocina de Puerto Rico. Considerando opciones alternas apropiadas para la producción agrícola de vegetales en Puerto Rico, se deben considerar los sustratos sin suelo para la producción de ají dulce. En este estudio se evaluaron cinco sustratos: (1) PRO-MIX® BX (BX); (2) PRO-MIX® BX + Micorrizas (BX + Myco); (3) PRO-MIX® Alta Porosidad + Micorriza (HP + Myco); (4) PRO-MIX® Alta Porosidad + Micorrizas + Biofungicida (HP + Myco + Fung); y (5) fibra de coco. Cuatro líneas experimentales de ají dulce (G-2, Sel-7, G-11 y G-8, que serán liberadas como ‹Amanecer›, ‹Bonanza›, ‹Carnaval› y ‹Pasión›, respectivamente) se evaluaron en cada sustrato. Se realizaron dos siembras, al aire libre y en tiestos, en una combinación factorial de cuatro líneas por cinco sustratos: Ensayo 1, de marzo a septiembre de 2017 y Ensayo 2, de octubre de 2017 a abril de 2018. Además, las cuatro líneas experimentales se trasplantaron al campo (Ensayo de Campo). Todas las siembras se realizaron en Mayagüez, Puerto Rico. Las diferencias entre sustratos fueron relativamente consistentes en el Ensayo 1 y el Ensayo 2. El ají dulce en BX + Myco y en HP + Myco + Fung floreció 50.3 días después del trasplante (DDT), mientras que las plantas creciendo en fibra de coco florecieron aproximadamente dos semanas y media después. Hubo poca o ninguna diferencia entre BX, BX + Myco y HP + Myco + Fung para altura de planta, número de frutos y peso total de frutos. El HP + Myco y la fibra de coco produjeron plantas más pequeñas, con pocas frutas y un peso de fruta más bajo. El peso promedio de frutas fue similar entre todos los sustratos. Las diferencias relativas entre líneas en los tres ensayos fueron menos consistentes que para los sustratos. La línea G-11 fue la de floración más temprana (50.1 DDT), así como la línea más pequeña. Las otras líneas florecieron de ocho a 10 días después. La línea más alta varió de ensayo a ensayo. La línea Sel-7 produjo el mayor número de frutos por planta en el Ensayo 1 y en el Ensayo de campo, mientras que G-2 y G-8 produjeron la mayor cantidad en el Ensayo 2. La línea Sel-7 tuvo el mayor peso total de frutos por planta en el Ensayo 1 y en el Ensayo de Campo, mientras que G-2 tuvo el mayor peso total en el Ensayo 2. A pesar del alto número de frutos en las plantas de G-8, los rendimientos fueron 60% menores debido al bajo peso promedio del fruto. La línea Sel-7 tuvo el mayor peso promedio de fruta en el Ensayo 1, mientras que G-11 tuvo el mayor peso de fruto en el Ensayo 2. Esta investigación sugiere que, debido a su menor costo, BX sería una buena opción de sustrato sin suelo para la producción de ají dulce. Para la producción de ají dulce en tiestos, las líneas G-2 y Sel-7 serían mejores que las líneas G-8 y G-11.

Palabras clave: ají dulce, pimiento tipo Habanero, fibra de coco, micorriza, biofungicida

INTRODUCTION

Sweet chili pepper (*Capsicum chinense* Jacq.) is one of the five domesticated species of the genus *Capsicum* and may be a progenitor of other species (Bosland, 1996; Eshbaugh, 1993). Fruits are generally small to medium in size, averaging 2 to 7 cm in diameter and 2 to 10 cm in length. The Amazonian South America is the center of diversity of *C. chinense* and the species later spread to the Caribbean. Although *C. chinense* species originated in the New World, it was named in 1776 by a French taxonomist who thought it came from China (Moscone et al., 2007; Barboza and De Bem Bianchetti, 2005). Although most cultivars of *C. chinense* are very pungent (for example, Habanero-type peppers popular in Mexican cuisine and Scotch Bonnet-type peppers on the English-speaking islands of the Caribbean), fruits of most plants of these species in Puerto Rico have little or no pungency. The term "sweet chili pepper" that we use here recognizes that while the fruits of these species are usually referred to as "chilies" in English, plants of *C. chinense* in Puerto Rico appear to have been selected for their mild flavored fruits. In Puerto Rico, Cuba and the Dominican Republic sweet chili pepper is known as *ají dulce*; it is used as a seasoning and is an important ingredient for *sofrito* (Mangan et al., 2017).

In Puerto Rico, vegetables in general accounted for about 13% of the value of the island's crops with an economic contribution of $46.93 million to the gross domestic product (GDP), according to the most recently available statistics from 2014/15 (Department of Agriculture of Puerto Rico, 2015). Within the Solanaceae, tomatoes have the greatest economic importance, contributing $19.98 million to GDP. Among the remaining vegetables, *C. annuum* peppers, such as cooking and bell types, are among the crops with the highest economic importance with a value of $2.92 million. Sweet chili pepper has a similar value: $2.185 million. The unit value of the crop at the time of the 2015 report was $115.89 per 45.36 kg. Currently, according to farmers, the farm-level value of sweet chili pepper may be as much as $150 per 45.36 kg, making it an extremely high-value crop per unit of land area.

For decades, many parts of the world have suffered from a considerable reduction in land dedicated to agriculture due to increasing population and construction. To respond to the market demands of horticultural crop production outside of traditional field production, growers have used organic and inorganic substrates like perlite, rock wool, coconut fibers, peat, vermiculite, gravels and sand to grow vegetables and ornamentals (Butt et al., 2007). These alternative growing mediums potentially have a positive effect on the yield and the quality of important horticultural crops in the marketplace. Most commercial potting mixes used for pepper production are peat-based media with additives to improve texture, wettability, pH, and fertility (Kelley et al., 2009). The use of substrates can be economical regarding water consumption, and substrates make it easier to control plant nutrients, might allow early harvest of crops and require no fallow period after harvesting.

Because of its favorable physical and chemical properties, peat is the primary ingredient in horticultural container production. Peat originates in wetland ecosystems where organic matter is produced at a faster rate than it decomposes (Parish et al., 2008; Joosten et al., 2012). Plants from *Sphagnum* spp. are the principal source of peat. Peatlands play an important role in hydrology and water regulation and are also areas of important biodiversity. Peat extraction has severely degraded peatland ecosystems, and restoration efforts are underway (Grand-Clement et al., 2015). Thus, there is a growing interest in finding alternatives to horticultural peat.

Coconut husks (*Cocos nucifera* L.) can be processed to remove the long fibers and manufacture ropes, mats and other materials. The remaining shorter fibers can be compacted into bricks that are referred to as coconut coir or coconut coir dust. As an alternative solution, coconut coir has been studied around the world as a substitute for peat. Abad et al. (2002) compared *Sphagnum* peat to coconut coir from 13 sources in Asia, the Americas and Africa. Coir from all sources was slightly acidic. There was great variability in salinity among the various samples. Amounts of N, Ca, Mg were low while P and K were unexpectantly high. They concluded that coconut coir would be an appropriate peat substitute for container production of ornamentals. A number of studies have demonstrated that coconut coir can be successfully used in container production of various vegetable and ornamental crops such as strawberries (Cantliffe et al., 2007), cherry tomato (Ramírez-Arias et al., 2014), oak species (Mariotti et al., 2020), *Diffenbachia* (Stamps and Evens 1997), and *Camellia japonica* (Larcher and Scariot, 2009). But other studies have demonstrated that coconut coir can have negative effects on plant growth (Mazahreh et al., 2015).

In Puerto Rico, sweet chili pepper is mostly produced conventionally, that is, the plants are grown in fields. However, there are challenges to producing sweet chili pepper in the mountains of Puerto Rico. Farms in Puerto Rico are small with an average size of 23.27 ha (57.5 acres) (USDA NASS, 2017), and there is limited access to flat land. Considering the scarcity of land appropriate for field production in the mountainous areas of Puerto Rico, soilless alternatives for vegetable crop production should be considered. Sweet chili pepper has a high economic value that could potentially offset the expense of containers and substrates. This research evaluates the effects of different soilless substrates on the production and growth of four sweet chili pepper lines developed by the Agricultural Experiment Station at the University of Puerto Rico-Mayagüez.

MATERIALS AND METHODS

The treatments consisted of a factorial combination of four experimental lines of sweet chili pepper, G-2, Sel-7, G-11 and G-8. These lines are being considered for release by the University of Puerto Rico Agricultural Experiment Station (UPR-AES) under the cultivar names 'Amanecer', 'Bonanza', 'Carnaval', and 'Pasión', respectively. Each line was transplanted into five growing substrates: (1) PRO-MIX® BX (BX), (2) PRO-MIX® BX+ Mycorrhizae (BX+Myco), (3) PRO-MIX® HP + Mycorrhizae (HP+Myco), (4) PRO-MIX® HP + Mycorrhizae + Biofungicide (HP+Myco+Fung), and (5) coconut coir. Substrate HP+Myco+Fung contains a naturally occurring strain of *Bacillus pumilus*. All substrates except the coconut coir bricks from UBICON (Woodridge, IL)[6] were commercial products from Primer Tech Horticulture (Quakertown, PA).

Two trials in containers of 9.5 L, each with a factorial combination of four lines by five substrates, took place on an outdoor terrace at UPR-Mayagüez: Trial 1 from March to September 2017 and Trial 2 from October 2017 to April 2018. In addition, the same seedlings produced for Trial 1 were also transplanted to the field at the UPR-Mayagüez Alzamora Laboratory Farm (Field Trial). For each trial, seeds of the four lines were initially planted in 72-cell plastic trays with cells measuring 3.2-cm wide at the top with a depth of 4.5 cm. All seeding trays were filled with BX. Trays were planted with two seeds per cell and thinned to a single seedling at approximately two weeks after seeding. Plants were watered by hand as needed. A solution with a concentration of 4 g of 20N-8.74P-16.6K in 1 L of water was used to fertilize seedlings once a week. Seedlings were transplanted to 9.5 L plastic pots at six weeks (Trial 1) and eight weeks (Trial 2) after seeding. Seedlings of the Field Trial were transplanted 6.5 weeks after seeding. In Trial 1 and 2, each line by substrate combination was replicated in five pots for a total of 100 pots per trial. In the Field Trial, the number of replicates (individual plants) per line varied from 9 to 18. In Trial 1 and 2, a total of 100 ml of the fertilizer solution described previously was added to each pot every three weeks beginning a week after transplanting. In the Field Trial, two applications of granular fertilizer (10N-10P-10K) were applied in a circle around each plant two weeks and six weeks after transplanting at a rate of 100 kg of N per hectare.

[6]Company or trade names in this publication are used only to provide specific information. Mention of a company or trade name does not constitute an endorsement by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

Plant height, number of days after transplanting (DAT) to first flower, total number of fruits per plant, total fruit weight per plant, and average fruit weight were measured. Height was measured every two weeks beginning approximately three weeks after transplanting. Harvesting began when the fruits turned from green to orange or red. Harvesting was done on a weekly basis or as needed. For Trial 1, seven harvests took place over a 14-week period. In Trial 2, there were 10 harvests over a period of 15 weeks. In the Field Trial six harvests were completed over an 11-week period. At each harvesting, the number of fruits and fruit weight per plant were recorded. Average fruit weight was determined by dividing the total fruit weight by total number of fruits. At the end of Trial 2, a single plant of each combination of cultivar and substrate was pulled from its pot. The roots were washed, and a photograph was taken.

The data of each of the three trials (Trial 1, Trial 2 and the Field Trial) were analyzed separately using a factorial analysis (four lines x five substrates) within a one-way analysis of variance (ANOVA). Substrate and line means were compared using Fisher's Least Significant Difference at the 0.05 probability level. ANOVAs and means separations were done using InfoStat (Di Rienzo et al., 2018).

RESULTS

Trial 1 ran from the first week of March to the second week of September 2017. Ambient conditions in Trial 1 were typical of those for the rainy season in Mayagüez, Puerto Rico, with an average daily high of 31.5° C and average daily low of 22.9° C. Trial 2 ran from the first week of October 2017 to the second week of April 2018. Ambient conditions were typical of those for the dry season with an average daily high of 30.2° C and average daily low of 21.4° C.

Trial 1 was severely impacted by infestations of thrips (*Frankliniella* spp.) and whiteflies (*Bemisia tabaci* Gennadius). About 30% of seedlings died. The number of dead plants among seedlings transplanted into HP+Myco and coconut coir was so high that all data from these two substrates was eliminated from the analysis in Trial 1.

Although there was considerable variability in plant height among the various treatment combinations, there was little variation in the average plant height per trial; plant height ranged from 47.7 cm in Trial 2 to 50.1 cm in the Field Trial (Table 1). However, means in Trial 1 were considerably lower than those of Trial 2 and the Field Trial (which took place at the same time as Trial 1) for number of fruits, total fruit weight and average fruit weight (Tables 2 to 4). Number of fruits and total fruit weight in Trial 1 was only about 30% to 35% of amounts

TABLE 1.—*Mean number of days to flower and plant height of four experimental lines of sweet chili pepper grown in outdoor containers with five substrates (Trial 1 and Trial 2) and in the field (Field Trial) at Mayagüez, Puerto Rico. Seedlings of Trial 1 and the Field Trial were transplanted in March 2017. Seedlings of Trial 2 were transplanted in October 2017.*

	Days to flower[2]	Plant height[3] (cm)		
Treatment[1]	Trial 2	Trial 1	Trial 2	Field Trial
Substrate				
BX	57.9 b[4]	53.8 a	48.4 ab	—
BX+Myco	51.9 c	43.9 a	49.1 ab	—
HP+Myco+Fung	48.6 c	51.8 a	51.5 a	—
HP+Myco	62.3 b	—[5]	46.4 bc	—
Coconut coir	68.7 a	—	43.0 c	—
Line				
G-2 (Amanecer)	58.6 a	46.6 b	54.0 a	52.9 b
Sel-7 (Bonanza)	61.6 a	61.1 a	45.9 b	61.8 a
G-11 (Carnaval)	50.1 b	32.0 c	39.7 c	32.9 c
G-8 (Pasión)	61.2 a	54.5 ab	51.2 a	52.8 b
Substrate x line				
BX - G-2	57.2 cdef	54.0 abc	53.8 ab	—
BX - Sel-7	62.8 bcd	69.3 a	46.8 bcd	—
BX - G-11	47.3 fgh	34.3 de	40.0 de	—
BX - G-8	64.4 abc	52.8 abcd	53.2 b	—
BX+Myco - G-2	48.0 efgh	36.3 cde	56.0 ab	—
BX+Myco - Sel-7	58.5 bcdef	52.3 abcd	46.0 bcde	—
BX+Myco - G-11	44.7 gh	---	40.0 de	—
BX+Myco - G-8	56.3 cdefg	45.7 bcde	54.3 ab	—
HP+Myco+Fung - G-2	53.3 defg	47.6 bcde	61.8 a	—
HP+Myco+Fung - Sel-7	50.0 efgh	59.8 ab	46.8 bcd	—
HP+Myco+Fung - G-11	41.0 h	29.7 e	44.0 cde	—
HP+Myco+Fung - G-8	50.0 efgh	61.2 ab	53.8 ab	—
HP+Myco - G-2	60.4 bcd	—	49.8 bc	—
HP+Myco - Sel-7	63.5 abcd	—	49.0 bcd	—
HP+Myco - G-11	59.0 bcde	—	38.0 e	—
HP+Myco - G-8	66.2 abc	—	48.8 bcd	—
Coconut coir - G-2	74.0 a	—	48.7 bcd	—
Coconut coir - Sel-7	73.3 a	—	41.0 de	—

[1]BX = PRO-MIX®BX; BX+Myco = PRO-MIX®BX with Mycorrhizae; HP+Myco = PRO-MIX® High Porosity with Mycorrhizae; HP+Myco+Fung = PRO-MIX® High Porosity with Mycorrhizae and Biofungicide. Substrate means are averaged over all lines. Line means are averaged over all substrates. Proposed cultivar name for each experimental line is given in parenthesis.

[2]Days from transplanting to the appearance of the first open flower.

[3]Plant height at 126 days after transplanting in Trial 1 and Trial 2, and at 122 days after transplanting in Field Trial.

[4]Within a column and type of treatment, means followed by a common letter are not significantly different at the 0.05 probability level according to Fisher's Least Significant Difference.

[5]— Missing treatment (Trial 1) or treatment not included (Field Trial).

TABLE 1.—(Continued) *Mean number of days to flower and plant height of four experimental lines of sweet chili pepper grown in outdoor containers with five substrates (Trial 1 and Trial 2) and in the field (Field Trial) at Mayagüez, Puerto Rico. Seedlings of Trial 1 and the Field Trial were transplanted in March 2017. Seedlings of Trial 2 were transplanted in October 2017.*

	Days to flower[2]	Plant height[3] (cm)		
Treatment[1]	Trial 2	Trial 1	Trial 2	Field Trial
Substrate				
Coconut coir - G-11	58.4 cdef[4]	—[5]	36.4 e	—
Coconut coir - G-8	69.3 ab	—	45.8 bcde	—
Overall mean	57.9	49.8	47.7	50.1
CV	12.5%	25.7%	12.7%	18.2%

[1]BX = PRO-MIX®BX; BX+Myco = PRO-MIX®BX with Mycorrhizae; HP+Myco = PRO-MIX® High Porosity with Mycorrhizae; HP+Myco+Fung = PRO-MIX® High Porosity with Mycorrhizae and Biofungicide. Substrate means are averaged over all lines. Line means are averaged over all substrates. Proposed cultivar name for each experimental line is given in parenthesis.

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[4]Within a column and type of treatment, means followed by a common letter are not significantly different at the 0.05 probability level according to Fisher's Least Significant Difference.

[5]— Missing treatment (Trial 1) or treatment not included (Field Trial).

in Trial 2 and the Field Trial. Average fruit weight in Trial 1 was about 70% of that in the other two trials.

Number of days after transplanting (DAT) to first open flower was not recorded in Trial 1. However, it seems clear that flowering occurred later in Trial 1 compared to Trial 2 since the first harvest in Trial 1 was carried out 92 DAT, while the first harvest in Trial 2 was much earlier at 76 DAT. The first harvest in the field control trial was also much earlier (76 DAT) than that of Trial 1. In Trial 2, plants in BX+Myco and in HP+Myco+Fung were the earliest to flower while plants in containers of coconut coir flowered about 20 days later (Table 1). Line G-11 was the earliest flowering with its first flowers opening on average at 50.1 DAT. The other three lines flowered eight to 11 days later. Line G-11 planted in HP+Myco+Fung resulted in the treatment combination with the earliest flowering 41.0 DAT, although that mean was not significantly different from several other substrate x line combinations.

At 126 DAT there were no differences in plant height among substrates BX, BX+Myco and HP+Myco+Fung in Trial 1 and 2 (Table 1). In Trial 2 coconut coir produced significantly shorter plants than BX, BX+Myco and HP+Myco+Fung. In Trial 1 height measurements were continued until 189 DAT but relative differences between substrates did not change (Figure 1). In all three trials G-11 was consistently the

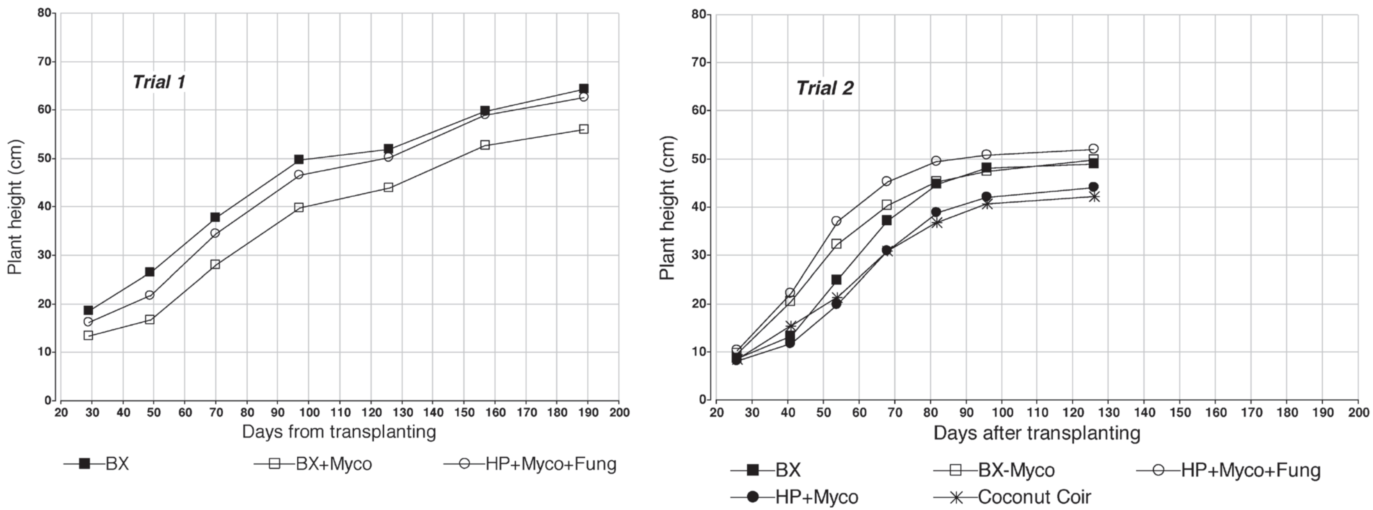

FIGURE 1. Plant height over time of sweet chili pepper grown outdoors in containers using three (Trial 1) or five (Trial 2) substrates. BX = PRO-MIX®BX; BX+Myco = PRO-MIX®BX with Mycorrhizae; HP+Myco = PRO-MIX® High Porosity with Mycorrhizae; HP+Myco+Fung = PRO-MIX® High Porosity with Mycorrhizae and Biofungicide. Heights were averaged over four sweet chili pepper lines. Trial 1 and 2 were transplanted in March 2017 and October 2017, respectively.

shortest line. Relative differences in height among the other three lines varied depending on the trial, as did the relative differences among substrate-line combinations (Table 1; Figure 2).

The number of fruits per plant and total fruit weight per plant did not vary greatly among substrates BX, BX+Myco and HP+Myco+Fung (Tables 2 and 3). Substrates HP+Myco and coconut coir produced plants with significantly fewer fruits and lower yields than the other three substrates, with coconut coir exhibiting a particularly poor performance. Line Sel-7 produced the largest number of fruits per plant and the highest yields in Trial 1 and in the Field Trial and these means were considerably higher than those of other lines (Table 2 and 3). Lines G-2 and G-8 produced the largest number of fruits per plant in Trial 2. However, total fruit weight of G-8 in Trial 2 was only 60% of that of G-2 due to the much smaller average fruit weight of G-8 (Table 3 and 4). Line G-2 in BX and in HP+Myco+Fung were among the highest yielding line-substrate combinations in Trial 2.

Average fruit weight varied among substrates by 1.0 g in Trial 1 (no significant differences) and by 1.5 g in Trial 2 (small significant differences) (Table 4). Lines G-11 and Sel-7 generally were the lines with the greatest average fruit weight, with Sel-7 tending to have heavier fruit than other lines in Trial 1 and G-11 having heavier fruit than other lines in Trial 2 and the Field Trial. Line G-8 had the lowest average fruit weight in two of the three trials. Line Sel-7 planted in BX, BX+Myco and HP+Myco+Fung had the best line-substrate combinations in Trial 1 while G-11 in the same substrates had the best combinations in Trial 2.

Observations (photographs of roots) taken in Trial 2 indicated that plants in HP+Myco+Fung develop large root masses that grew deep. Plants in BX and BX+Myco also had well-developed roots. Plants in coconut coir and HP+Myco grew deeper than plants in other substrates.

DISCUSSION

The commercial PROMIX substrates included in this study were chosen because they are generally available in Puerto Rico and offered the opportunity to study the usefulness of additions such as mycorrhizae and biofungicide. The primary ingredient of all PROMIX substrates is sphagnum peat moss. Peat moss has properties that make it an ideal plant substrate including high water retention and low bulk density due to its high organic matter content. In addition to peat moss, PROMIX substrates also include perlite and vermiculite to improve nutrient holding capacity and increase porosity (Table 5). The higher percentage of peat moss in BX and BX+Myco make those

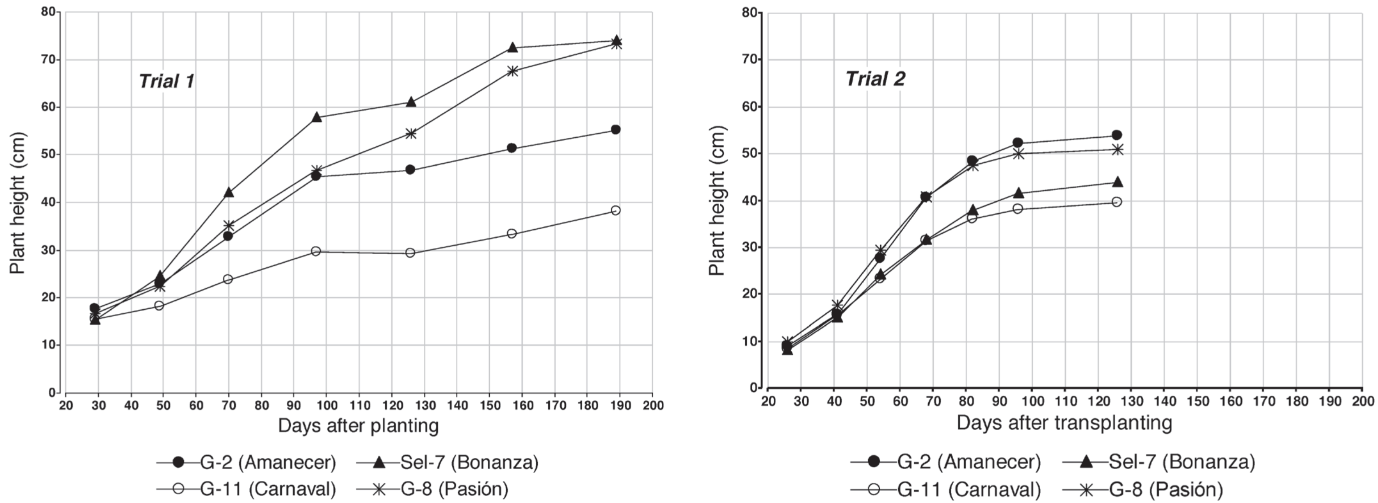

FIGURE 2. Plant height over time in four experimental lines of sweet chili pepper grown outdoors in containers. The cultivar name proposed for each experiment line is given in parenthesis. Heights were averaged over three container substrates in Trial 1 and over five container substrates in Trial 2. Trial 1 and 2 were transplanted in March 2017 and October 2017, respectively.

TABLE 2.—*Mean number of fruits per plant of four experimental lines of sweet chili pepper grown in outdoor containers with five substrates (Trial 1 and Trial 2) and in the field (Field Trial) at Mayagüez, Puerto Rico. Seedlings of Trial 1 and the Field Trial were transplanted in March 2017. Seedlings of Trial 2 were transplanted in October 2017.*

	Number of fruits per plant		
Treatment[1]	Trial 1	Trial 2	Field Trial
Substrate			
BX	32.5 a[2]	72.2 b	—
BX+Myco	18.1 b	79.6 ab	—
HP+Myco+Fung	21.0 ab	90.3 a	—
HP+Myco	—[3]	55.2 c	—
Coconut coir	—	38.2 d	—
Line			
G-2 (Amanecer)	19.4 b	88.6 a	66.4 bc
Sel-7 (Bonanza)	40.0 a	58.1 b	125.6 a
G-11 (Carnaval)	9.5 b	44.9 c	48.5 bc
G-8 (Pasión)	16.9 b	77.0 a	40.3 c
Substrate x line			
BX - G-2	30.0 ab	107.6 ab	—
BX - Sel-7	50.6 a	60.3 defg	—
BX - G-11	7.0 b	42.8 fgh	—
BX - G-8	23.3 b	78.2 cde	—
BX+Myco - G-2	7.5 b	83.0 bcde	—
BX+Myco - Sel-7	31.7 ab	74.5 cdef	—
BX+Myco - G-11	—	64.0 defg	—
BX+Myco - G-8	8.5 b	97.0 abc	—
HP+Myco+Fung - G-2	9.7 b	121.0 a	—
HP+Myco+Fung - Sel-7	34.4 ab	68.3 cdef	—
HP+Myco+Fung - G-11	12.0 b	57.3 defgh	—
HP+Myco+Fung - G-8	16.0 b	114.8 ab	—
HP+Myco - G-2	—	84.2 bcd	—
HP+Myco - Sel-7	—	51.0 efgh	—
HP+Myco - G-11	—	31.0 h	—
HP+Myco - G-8	—	54.6 efgh	—
Coconut coir - G-2	—	47.0 fgh	—
Coconut coir - Sel-7	—	36.3 gh	—
Coconut coir - G-11	—	29.2 h	—
Coconut coir - G-8	—	40.5 gh	—
Overall mean	23.9	67.1	70.2
CV	67.1%	20.9%	25.1%

[1]BX = PRO-MIX®BX; BX+Myco = PRO-MIX®BX with Mycorrhizae; HP+Myco = PRO-MIX® High Porosity with Mycorrhizae; HP+Myco+Fung = PRO-MIX® High Porosity with Mycorrhizae and Biofungicide. Substrate means are averaged over all lines. Line means are averaged over all substrates. Proposed cultivar name for each experimental line is given in parenthesis.

[2]Within a column and type of treatment, means followed by a common letter are not significantly different at the 0.05 probability level according to Fisher's Least Significant Difference.

[3]— Missing treatment (Trial 1) or treatment not included (Field Trial).

TABLE 3.—*Mean total weight per plant of four experimental lines of sweet chili pepper grown in outdoor containers with five substrates (Trial 1 and Trial 2) and in the field (Field Trial) at Mayagüez, Puerto Rico. Seedlings of Trial 1 and the Field Trial were transplanted in March 2017. Seedlings of Trial 2 were transplanted in October 2017.*

	Total fruit weight per plant (g)		
Treatment[1]	Trial 1	Trial 2	Field Trial
Substrate			
BX	343.3 a[2]	885.4 a	—
BX+Myco	211.9 a	967.5 a	—
HP+Myco+Fung	197.3 a	996.3 a	—
HP+Myco	—[3]	661.4 b	—
Coconut coir	—	433.9 c	—
Line			
G-2 (Amanecer)	148.3 b	1,001.6 a	840.8 b
Sel-7 (Bonanza)	497.1 a	747.8 bc	1,700.6 a
G-11 (Carnaval)	88.0 b	783.2 b	718.7 b
G-8 (Pasión)	112.4 b	623.0 c	271.8 c
Substrate x line			
BX - G-2	243.7 bc	1,236.0 ab	—
BX - Sel-7	659.9 a	776.5 cdef	—
BX - G-11	59.5 bc	830.4 cde	—
BX - G-8	170.6 bc	698.6 def	—
BX+Myco - G-2	53.0 bc	914.2 bcde	—
BX+Myco - Sel-7	417.6 ab	1,005.2 abcd	—
BX+Myco - G-11	—	1,101.7 abc	—
BX+Myco - G-8	62.4 bc	849.1 cde	—
HP+Myco+Fung - G-2	52.8 c	1,339.8 a	—
HP+Myco+Fung - Sel-7	382.1 b	904.5 cde	—
HP+Myco+Fung - G-11	116.6 bc	927.4 bcde	—
HP+Myco+Fung - G-8	87.6 bc	813.6 cde	—
HP+Myco - G-2	—	990.6 bcd	—
HP+Myco - Sel-7	—	616.7 defg	—
HP+Myco - G-11	—	582.1 efg	—
HP+Myco - G-8	—	456.2 fg	—
Coconut coir - G-2	—	527.2 efg	—
Coconut coir - Sel-7	—	436.3 fg	—
Coconut coir - G-11	—	474.4 fg	—
Coconut coir - G-8	—	297.7 g	—
Overall mean	250.8	788.9	883.0
CV	81.8%	31.5%	27.1%

[1]BX = PRO-MIX®BX; BX+Myco = PRO-MIX®BX with Mycorrhizae; HP+Myco = PRO-MIX® High Porosity with Mycorrhizae; HP+Myco+Fung = PRO-MIX® High Porosity with Mycorrhizae and Biofungicide. Substrate means are averaged over all lines. Line means are averaged over all substrates. Proposed cultivar name for each experimental line is given in parenthesis.

[2]Within a column and type of treatment, means followed by a common letter are not significantly different at the 0.05 probability level according to Fisher's Least Significant Difference.

[3]—Missing treatment (Trial 1) or treatment not included (Field Trial).

TABLE 4.—*Mean average fruit weight of four experimental lines of sweet chili pepper grown in outdoor containers with five substrates (Trial 1 and Trial 2) and in the field (Field Trial) at Mayagüez, Puerto Rico. Seedlings of Trial 1 and the Field Trial were transplanted in March 2017. Seedlings of Trial 2 were transplanted in October 2017.*

	Average fruit weight (g)		
Treatment[1]	Trial 1	Trial 2	Field Trial
Substrate			
BX	9.5 a[2]	13.2 a	—
BX+Myco	8.9 a	12.6 abc	—
HP+Myco+Fung	8.5 a	11.9 bc	—
HP+Myco	—[3]	12.7 ab	—
Coconut coir	—	11.7 c	—
Line			
G-2 (Amanecer)	6.9 b	11.3 c	12.5 c
Sel-7 (Bonanza)	11.8 a	12.8 b	13.5 b
G-11 (Carnaval)	9.2 ab	17.6 a	14.8 a
G-8 (Pasión)	7.0 b	8.1 d	6.8 d
Substrate x line			
BX - G-2	7.9 cd	11.3 de	—
BX - Sel-7	12.5 a	13.0 de	—
BX - G-11	8.6 bcd	19.6 a	—
BX - G-8	7.7 cd	8.9 fg	—
BX+Myco - G-2	6.6 cd	11.0 ef	—
BX+Myco - Sel-7	11.5 ab	13.5 d	—
BX+Myco - G-11	—	17.3 bc	—
BX+Myco - G-8	7.3 cd	8.7 fgh	—
HP+Myco+Fung - G-2	5.4 d	11.1 e	—
HP+Myco+Fung - Sel-7	11.3 ab	13.3 d	—
HP+Myco+Fung - G-11	9.7 abc	16.1 c	—
HP+Myco+Fung - G-8	6.1 cd	7.2 h	—
HP+Myco - G-2	—	11.7 de	—
HP+Myco - Sel-7	—	11.9 de	—
HP+Myco - G-11	—	18.9 ab	—
HP+Myco - G-8	—	8.3 gh	—
Coconut coir - G-2	—	11.2 de	—
Coconut coir - Sel-7	—	12.3 de	—
Coconut coir - G-11	—	16.1 c	—
Coconut coir - G-8	—	7.3 gh	—
Overall mean	9.0	12.4	11.9
CV	22.8%	10.2%	3.7%

[1]BX = PRO-MIX®BX; BX+Myco = PRO-MIX®BX with Mycorrhizae; HP+Myco = PRO-MIX® High Porosity with Mycorrhizae; HP+Myco+Fung = PRO-MIX® High Porosity with Mycorrhizae and Biofungicide. Substrate means are averaged over all lines. Line means are averaged over all substrates. Proposed cultivar name for each experimental line is given in parenthesis.

[2]Within a column and type of treatment, means followed by a common letter are not significantly different at the 0.05 probability level according to Fisher's Least Significant Difference.

[3]—Missing treatment (Trial 1) or treatment not included (Field Trial).

TABLE 5.—*Comparison of ingredients in four commercial substrates used in the study. Percentages are of total volume.*

Ingredient[1]	BX[2]	BX+Myco	HP+Myco	HP+Myco+Fung
Sphagnum peat moss	75-85%	75-85%	65-75%	65-75%
Perlite	10-14%	10-14%	8-35%	8-35%
Vermiculite	P	P	P	P
Limestone	P	P	P	P
Mycorrhizae (*Glomus intraradices*)		P	P	P
Biofungicide (*Bacillus pumilus*)				P

[1]As indicated on Safety Data Sheets and webpage of Premier Tech Horticulture.

[2]BX = PRO-MIX®BX; BX+Myco = PRO-MIX®BX with Mycorrhizae; HP+Myco = PRO-MIX® High Porosity with Mycorrhizae; HP+Myco+Fung = PRO-MIX® High Porosity with Mycorrhizae and Biofungicide.

substrates less porous and better at retaining water than HP+Myco and HP+Myco+Fung. However, high water retention ability can be a disadvantage in containers that are exposed to a high level of moisture over extended periods of time. Each of the trials ran over a six-month period, and each trial had periods when containers were exposed to high amounts of rainfall.

Plants colonized by mycorrhizal fungi have been shown to have improved nutrient and water absorption, and increased plant growth and disease resistance (Bonfante and Genre, 2010). Aponte López (2018) demonstrated that plants of sweet chili pepper planted on the UPR-Mayagüez campus were colonized by local mycorrhizae. Further studies by Aponte López (2018) demonstrated the positive effects of mycorrhizae on the growth of *ají dulce* planted in containers. In her study, growth of *C. annuum* was greater with BX+Myco compared to BX or BX+garden soil.

Biofungicides are formulations that include living organisms. Substrate HP+Myco+Fung contains *Bacillus pumilus* and is promoted by the manufacturer of PROMIX® as a means of controlling *Fusarium*, *Pythium* and *Rhizoctonia.* In general, sweet chili pepper grown in HP+Myco+Fung did very well in our study. Since we did not specifically test for infection by these pathogens, no conclusions can be made as to whether a lower incidence of these pathogens explains why plants in HP+Myco+Fung performed well in this study.

Coir alone is often acidic (Abad et al., 2002), and salinity can also be a problem in some sources of coconut coir. Low pH is a characteristic of peat moss, and some peat-based PROMIX® products have added limestone as a way of reducing acidity. Mazahreh et al. (2015) showed that cucumbers grown in coir alone had poorer production than cucumbers grown in a mix of coir and peat moss. Larcher and Scariot (2009) also demonstrated that coconut coir should not completely replace peat in container production but could replace about 30% of a peat-agriperlite substrate mix.

Substrates HP+Myco and coconut coir were originally included in Trial 1 but plants in those substrates were heavily impacted by damage from infestations of whiteflies and thrips. Because of the extensive damage to plants, these treatments were eliminated from the analysis of Trial 1. Sweet chili pepper planted in HP+Myco and coconut coir fared poorly in Trial 2 as well, although there was no notable damage from insects, disease or pathogens. In general, these substrates produced the shortest plants with the least number of fruits per plant and the lowest total fruit weight per plant, although these outcomes were not always significantly different from other substrates (Tables 1 to 3). Plants in coconut coir were also among those substrates producing fruits with the lowest average fruit weight (Table 4). However, the differences in average fruit weight among the five substrates were very small.

Plants in HP+Myco performed poorly, while plants in a similar high-porosity product, HP+Myco+Fung, did well. This might be primarily the result from the positive effects of the biofungicide. Coconut coir is also a high porosity product that is similar to HP+Myco in terms of physical properties. In this study, coconut coir also resulted in poor plant growth and production. Growing media need good balance between porosity (for proper aeration) and water-holding capacity. They also must allow for adequate nutrient uptake. Unamended, high porosity products like HP+Myco and coconut coir may not meet that criterion.

Except for Sel-7, production in Trial 2 compared favorably with field production. Although no direct statistical comparison is possible, container production of some lines appeared to be superior to field production (Tables 1 to 4). However, Sel-7 grew slightly taller, produced more fruits, and had greater fruit weight per plant in the field compared to containers.

The same amount and frequency of fertilization and irrigation was used for all substrates. It is very likely that different protocols are needed for different substrates, particularly for coconut coir compared to peat substrates. For a particular substrate, irrigation and fertilization schedules need to be developed to maximize plant development and nutrient use, and at the same time minimize nutrient losses that can harm the environment.

The results suggest that the use of BX as substrate produces the best results for several growth parameters including total days to flowering, number of fruits per plant, and average fruit weight. BX also has the advantage of lower cost compared to other PROMIX products. Lines G-2 and Sel-7 are recommended as the best sweet chili pepper lines for container production. Future research should study the various substrates used in Puerto Rico for soilless container production of other vegetables and ornamentals. The effect of various fertilization regimes also needs to be studied; fertilization requirements may vary among substrates. The possible benefits of mixed substrates (soil amended with soilless substrates) could also be studied. Effort should be made to look for local sources of substrates that are less expensive and better for the environment and pest control. Additional studies should be conducted to determine the effectiveness of the use of containers in the production of sweet chili pepper compared with production directly in the soil. Surveys can be developed by the Agricultural Extension Service at the University of Puerto Rico at Mayagüez to determine the acceptance of soilless substrates evaluated in this study among local producers of sweet chili pepper.

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