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Yield, Fruit Quality, and Growth of 4 Cantaloupe Varieties Grown in Hydroponic System and Drip Irrigation Systems of Substrate and Soil Culture

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At present, the cantaloupe plants are mostly grown under the open soil field condition during weather with frequent heavy rain that caused the loss of nutrients from the soil resulting in low yield and bad fruit quality. The study aimed to assess yield, fruit quality, and growth of four cantaloupe varieties grown in NFT hydroponic system and drip irrigation substrate culture system and drip irrigation soil culture system. The assigned treatments were cantaloupe variety and the planting system. The ten treaments were: Alpha TA209, Emerald Sweet 1225, and Sin Jiang TA212 grown in hydroponic system; Alpha TA209, Emerald Sweet 1225, Sin Jiang TA212, and Golden Lady 1382 grown in drip irrigation substrate culture system; and Alpha TA209, Emerald Sweet 1225, and Sin Jiang TA212 grown in drip irrigation soil culture system. The results showed that the yields of Alpha TA209, Emerald Sweet 1225, Sin Jiang TA212, and Golden Lady 1382 grown in drip irrigation substrate culture system were higher than in NFT hydroponic system and drip irrigation soil culture system, attributable to better fruit weight, flesh thickness, fruit height, and fruit diameter. These fruit qualities were positively associated with yield. Golden Lady 1382 grown in drip irrigation substrate culture system gave the highest yield at 24.14 t ha^{-1} and the heaviest fruit weight at 1.25 kg $fruit^{-1}$ compared with the rest, while Sin Jiang TA212 grown in drip irrigation soil culture system obtained the lowest yield and fruit weight. Most of the cantaloupe varieties had high total soluble solids content (TSSC) observed in the three planting systems, except Emerald Sweet 1225 and Sin Jiang TA212 grown in drip irrigation soil culure system. Based on correlation analysis, plant height was positively associated with fruit diameter, fruit height, flesh thickness, TSSC, fruit weight, and yield. Plant height was the tallest in drip irrigation substrate culture system than in drip irrigation soil culture system and NFT hydroponic system. Therefore, drip irrigation substrate culture system is the best cantaloupe planting system.

Keywords: Cantaloupe, yield, fruit quality, NFT hydroponic system, drip irrigation substrate culture system

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Introduction

Cantaloupe (*Cucumis melo* L.) is a tropical fruit plant. It is one of the important economic crops in Thailand, making a great income for Thai farmers. The total growing area for cantaloupe in Thailand was about 2,000 hectares. These areas are in Aranyaprathet district in Sa Kaeo province, Ladkrabang district in Bangkok, and Chiang Mai province (Kusuma Na Ayuthaya, 2016). The province of Chanthaburi has the climate similar to those above mentioned areas, hence it is one of the suitable planting areas for cantaloupe production in Thailand. Presently, the cantaloupe plants are mostly grown under the open soil field condition during weather with frequent heavy rain that caused the loss of nutrients from the soil, resulting in a low yield and bad fruit quality. New cantaloupe varieties that give high quality and good yield are introduced to the farmers in the province of Chanthaburi, such as Alpha TA209, Emerald Sweet 1225, Sin Jiang TA212 and Golden Lady 1382. Good soils such as loam, sandy loam, and sandy clay loam soils with good drainage and aeration are often used to grow the cantaloupe plants. Soils with good water holding capacity, however, would have a tendency to absorb more water resulting in a decreased sweetness and crunchiness of the fruit. Senanunsakul (1997) reported that the average fruit weight of cantaloupe obtained in nutrient film technique (NFT) hydroponic system under a shed with a roof sloping backwards and without supporting poles was not significantly different compared with the average fruit weight obtained in substrate culture grown under a shed with a two-layered curved roof. It is therefore important to find out the suitable production method for each cantaloupe variety to obtain better growth, yield and quality. The study aimed to assess yield, fruit quality, and growth of four cantaloupe varieties grown in NFT hydroponic system and drip irrigation substrate culture system and drip irrigation soil culture system.

Materials and Methods

The experiment station was located at the Division of Crop Production and Landscape Technology, Faculty of Agro-Industrial Technology, Rajamangala University of Technology Tawan-Ok Chanthaburi Campus in Chanthaburi, Thailand. It was conducted during April to July of 2016. The experiment was laid out in a randomized complete block design (RCBD), replicated four times, with each time comprised of 30 plants. The cantaloupe variety together with the planting system were assigned to be the treatments. Ten treaments comprised of Alpha TA209 grown in NFT hydroponic system (AlphaNFT), Emerald Sweet 1225 grown in NFT hydroponic system (EmeraldNFT), Sin Jiang TA212 grown in hydroponic system (SinNFT), Alpha

TA209 grown in drip irrigation substrate culture system (AlphaSUB), Emerald Sweet 1225 grown in drip irrigation substrate culure system (EmeraldSUB), Sin Jiang TA212 grown in drip irrigation substrate culture system (SinSUB), Golden Lady 1382 grown in drip irrigation substrate culture system (GoldSUB), Alpha TA209 grown in drip irrigation soil culture system (AlphaSOIL), Emerald Sweet 1225 grown in drip irrigation soil culture system (EmeraldSOIL) and Sin Jiang TA212 grown in drip irrigation soil culture system (SinSOIL).

Alpha TA209 variety has a round fruit shape; its skin (exocarp) has a dark green color and well netted while its flesh (mesocarp) has an orange color (Figure 1a). Emerald Sweet 1225 variety has a round fruit shape and its exocarpis very well netted; as it ripens, both its exocarp and mesocarp parts have a light-green color (Figure 1b). Sin Jiang TA212 variety has an oval fruit shape, its exocarp has a light yellowish color and its mesocarp has a light orange color (Figure 1c). Golden Lady 1382 variety has a round fruit shape, its exocarp is yellow and its mesocarp is white (Figure 1d).

(a) **(b)** **(c)** **(d)**

Figure 1. Fruit shape, exocarp and mesocarp colors of cantaloupe fruits : (a) Alpha TA209; (b) Emerald Sweet 1225; (c) Sin Jiang TA212; and (d) Golden Lady 1382

There were twelve sets of nutrient film technique (NFT) hydroponic tables prepared, each table had 1.2 m wide x 6.0 m long and plant spacing of 0.4 m x 0.6 m, 2 gullies table^{-1}, 15 holes gully^{-1}, along with 12 pieces of 35-watt submersible pumps (1 submersible pump table^{-1}). Ten-day old seedlings in the planting sponge were transplanted to the planting pots into the prepared NFT hydroponic tables, 30 seedlings table^{-1}, 1 seedling hole^{-1}. The seedlings of

Alpha TA209, Emerald Sweet 1225 and Sin Jiang TA212 varieties were grown in NFT hydroponic system. NFT was a recirculating hydroponic system where nutrient solution flows down to a set of gullies (also known as channels). The nutrient solutions A and B (Wiangsamut, 2016) were pumped within a holding container, through PVC pipes at the top of every sloping gully and the runoff from the bottom of the gullies was returned to the container. The nutrient solution A (200 ml per 80 L water) was applied in a container a day after transplanting then after 4 hours, the solution B (200 ml,) was also added. The electrical conductivity (EC) of the mixed nutrient solutions (A and B) diluted in the 80 liters of water were adjusted to the threshold of 1.0–1.5 dS m^{-1}. Likewise, the pH was adjusted to the threshold of 5.4–6.7. The EC and pH values were monitored every day at 0700H using EC and pH meters, respectively. The standing mixed nutrient solutions were maintained at 20–80 liters per container for the entire growing period, except 4 days before harvesting. These mixed nutrient solutions were drained and substituted with clean water to reduce the nitrate accumulation in the cantaloupe fruits. The mixed nutrient solutions were electrically circulated through the root system of the plants within 2–3 millimeters deep in the gullies. The total nutrient solutions A and B used for the entire growing period of cropping season was 1.7 L $table^{-1}$ for each solution. The NFT hydroponic system was in a protected cultivation shade house (with a plastic roof of 7% UV protection) to prevent damage from the rain during the early rainy season.

In addition, sixteen substrate plots were prepared by horizontally stacking 2 bricks on top of each other (brick size of 12.5 cm x 25.0 cm x 10.0 cm) to form a plot. Each plot size was 1.20 m wide x 6.00 m long x 0.15 m tall. A distance of 1 m between plots was also kept. Then, the plots were covered by a black plastic sheet to prevent the loss of water and fertilizer applied through seepage and percolation. The prepared planting medium (mixture of sand, rice husk ash, coconut coir, and cow dung with a ratio of 1:1:1:1 by volume) was placed in each plot with a 0.15 m height and then covered by a black plastic sheet. Holes were made on the plastic sheet cover with 0.4 m x 0.6 m spacing. Then before transplanting, thin bamboo poles were placed in each of the hole together with a small head of drip irrigation system. The drip irrigation culture system was in a protected cultivation shade house (with plastic roof of 7% UV protection) to prevent damage from the rain during the early rainy season.

Lastly, twelve sandy loam soil plots were prepared by a small tractor with 9 HP. Each plot size was 1.20 m wide x 6.00 m long x 0.25 m tall; keeping a distance of 1 m between plots. The soil surface was covered by a black plastic sheet where planting holes (with plant spacing of 0.4 m x 0.6 m) were made. Before transplanting, thin bamboo poles were placed in the middle of each hole together with a small head of drip irrigation system. These soil plots were under open, sunlight condition. Ten-day old seedlings of Alpha TA209, Emerald Sweet 1225, Sin Jiang TA212, and Golden Lady 1382 were pulled out from the seedling medium trays (mixture of sand, rice husk ash, and coconut coir with a ratio of 1:1:1 by volume) then were transplanted to the prepared holed plots in drip irrigation substrate culture system, 1 seedling hole^{-1} or 1 seedling hill^{-1}, 30 seedlings plot^{-1}, and were also transplanted in drip irrigation soil culture plots, except Golden Lady 1382.

The seedlings were transplanted to the three planting systems (NFT hydroponic system and drip irrigation systems of substrate and soil culture) at the same day. As the seedlings developed and produced excessive vine growth, pruning was performed to achieve a balance between vine growth and fruit set. A suitable pruning treatment for cantaloupes was to retain a primary stem and one of the first secondary branches (laterals) while pruning all additional laterals up to, and, including the 6th-7th leaf node. All secondary branches at the 8th-12th leaf node were left unpruned for fruit set. Only one fruit per plant was retained. All secondary branches after the 12th leaf node were cut and the plant tip above the 25th leaf node on the primary stem was also cut.

Drip irrigation applied were done twice a day from 0700H to 0800H and from 1700H to 1800H in the substrate and soil culture plots, until the plants reached its physiological maturity stage. Urea [$CO(NH_2)_2$] (46% N) and chicken dung pellets (0.50%N, 0.25%P_2O_5, and 0.05%K_2O) were applied to the plants for 7 times, where application of 2.5 g plant^{-1} and 7 g plant^{-1} for each time, respectively. A basal fertilizer was applied first time; the 2nd to the 7th time were done at 20 days after sowing (DAS), 26 DAS, 33 DAS, 40 DAS, 47 DAS, and 54 DAS or 10 days after transplanting (DAT), 16 DAT, 23 DAT, 30 DAT, 37 DAT, and 44 DAT. The 13-13-21 chemical fertilizer (13%N, 13%P_2O_5, and 21%K_2O) and chicken dung pellets (0.50%N, 0.25%P_2O_5, and 0.05%K_2O) were also applied to the plants for 4 times, where application of 2.5 g plant^{-1} and 7 g plant^{-1} for each time, respectively; application was at 61 DAS, 68 DAS, 75 DAS, and 82 DAS or 51 DAT, 58 DAT, 65 DAT, and 72 DAT. The total urea [$CO(NH_2)_2$] (46% N) applied was 17.5 g plant^{-1}, the total chicken dung pellets was 49 g plant^{-1}, and the total 13-13-13 chemical fertilizer was 10 g plant^{-1}for the entire growing period.

The total nutrients available to the cantaloupe plants were analyzed through each planting medium from each planting system (NFT hydroponic system, drip irrigation substrate culture system, and drip irrigation soil culture system) after chemical fertizers were applied to the plants (Table 1).

Table 1. pH and total nutrients available to the cantaloupe plants accounted from the different planting systems for entried crop duration

Planting system	Total nutrients available to the plants (g $plant^{-1}$)					
	pH	**Total nitrogen**	**Total phosphorus**	**Total potassium**	**Total calcium**	**Total magnesium**
****NFT hydroponic**	5.4-6.7	3.0487	0.5766	3.7194	2.0400	0.5349
***[€]Substrate culture**	5.3	56.5350	1.4925	2.4850	46.8000	-
***Soil culture (sandy loam soil)**	5.71	70.5750	1.4928	2.4866	0.0022	0.0007

** Applied a nutrient solution to the plants in the NFT hydroponic system.

* Applied a chemical fertilizer in the solid form to the plants in the substrate and soil culture systems, and total nutrients available to a cantaloupe plant in an area of a 0.24 m^2 (planting space of 0.4 m x 0.6 m, 1 plant $hill^{-1}$) in a soil depth at 15 cm from soil surface or planting medium suface.

[€] Planting medium composed of sand, rice husk ash, coconut coir, and cow dung then mixed its with a ratio of 1:1:1:1 by volume.

Hand weeding was done in substrate and soil culture plots. Insects and diseases control were done as necessary. Fungicide (e.g. mancozeb) was mixed with insecticide (e.g. fipronil); 20 ml of mancozeb and 20 ml of fipronil was mixed and dissolved in 10 L of water and was then sprayed to the cantaloupe plants at 20 DAT, 27 DAT, 34 DAT, and 41 DAT. Yield, fruit quality, and plant growth of cantaloupe production were determined by taking 4 fruits per plot or 4 fruits per table at 90 DAS (physiological maturity) and were as follow: yield, fruit quality [fruit weight, fruit number, fruit diameter, flesh thickness, fruit height, total soluble solids content (TSSC)] and plant height.

Yield was determined for each cantaloupe fruit through a weighing scale in a unit of kilogram per unit area then converted its unit to a unit of tonne per hectare (t ha^{-1}). Fruit weight was determined by a weighing scale for each cantaloupe fruit weight in a unit of kilogram per fruit (kg $fruit^{-1}$). Fruit number or plant number was done by counting all number of fruits per unit area or all number of plants per unit area then converted it to a number of fruits per hectare (fruits ha^{-1}) or number of plants per hectare (plants ha^{-1}). Total soluble solids content (TSSC) was measured by dropping a few amount of extracted cantaloupe juice on a small glass reticle inside a hand refractometer then read the value of a liquid's refractive index in a unit of a percent brix (% brix). Flesh thickness was measured from the inner exocarp to the inner mesocarp of the fruit (cut crosswise) in a unit of centimeter (cm) using a vernier caliper. Fruit height was measured from the fruit tip to the fruit bottom by a vernier caliper in a unit of centimeter (cm). Fruit diameter was measured at the midpart, from the outer exocarp on one side to the outer exocarp on the other side using a vernier caliper in a unit of centimeter (cm). Plant height was measured as a plant growth from a base of the stem to the plant tip at the 25th leaf node on the same stem by a ruler in a unit of centimeter (cm) (Figure 2).

(a) **(b)** **(c)**

Figure 2. Plant height of cantaloupe (a) in NFT hydroponic system, (b) in drip irrigation substrate culture system, (c) in drip irrigation soil culture system

All plant parameters were analyzed through a statistical analysis system program. Means comparisons were done using the Duncan's Multiple Range Test (DMRT) at the 0.01 probability level. Relationships of yield and other plant parameters were done through a correlation analysis.

Results

A drip irrigation substrate culture system had the yields of 23.10-24.14 t ha^{-1} and fruit weight of 1.20-1.25 kg fruit^{-1}, appreciably higher than in an NFT hydroponic system of 11.59-14.09 t ha^{-1} and 0.60-0.73 kg fruit^{-1}, and a drip irrigation soil culture system of 4.44-12.55 t ha^{-1} and 0.23- 0.65 kg fruit^{-1} (Table 2).

AlphaSUB, EmeraldSUB, and SinSUB gave yield and fruit weight noticeably higher than AlphaNFT, EmeraldNFT, and SinNFT (Table 2). However, GoldSUB gave the highest yield at 24.14 t ha^{-1} and the heaviest fruit weight at 1.25 kg fruit^{-1} compared with the rest while SinSOIL obtained the lowest yield and fruit weight (Table 2). Yield was positively associated with fruit weight (r = 0.01), total soluble solids content (TSSC) (r = 0.45), flesh thickness (r = 0.87), fruit height (r = 0.85) and fruit diameter (0.93) (Table 3). This means that as fruit weight, TSSC, flesh thickness, fruit height, and fruit diameter increase, yield also increases. Fruit weight was positively associated with TSSC (r = 0.45), flesh thickness (r = 0.87), fruit height (r = 0.85) and fruit diameter (r = 0.93) (Table 3). This also means that as TSSC, flesh thickness, fruit height, and fruit diameter increase, fruit weight also increases.

Fruit number was the same as in NFT hydroponic system as drip irrigation systems of substrate, and soil culture, as its number were determined at physiological maturity stage, one fruit per plant with 19,313 fruits ha^{-1} (Table 2).

Total soluble solids content (TSSC) had a very significant difference as AlphaNFT, EmeraldNFT, SinNFT, AlphaSUB, EmeraldSUB, SinSUB, GoldSUB, AlphaSOIL had high fruit quality compared with EmeraldSOIL and SinSOIL (Table 2). SinSOIL had the lowest fruit quality in terms of TSSC. This was positively associated with flesh thickness (r = 0.61), fruit height (r = 0.40) and fruit diameter (r = 0.60) as flesh thickness, fruit height, and fruit diameter increase, TSSC also increases (Table 3).

Flesh thickness had a very significant difference as AlphaSUB and EmeraldSUB were higher than the others, while SinSOIL was the lowest (Table 2). The drip irrigation substrate culture system obtained flesh thickness of 2.95-3.73 cm, noticeably higher than in NFT hydroponic system with 2.45-3.30 cm, and drip irrigation soil culture system with 1.63-2.75 cm (Table 2).

Fruit height had a very significant difference as SinSUB (16.83 cm) and GoldSUB (15.10 cm) were higher than the rest. The drip irrigation substrate culture system gave the fruit height of 12.00-16.83 cm considerably higher than in NFT hydroponic system with 9.75-12.30 cm, and drip irrigation soil culture system with 8.10-9.50 cm (Table 2). Fruit height was positively associated with fruit diameter (r = 0.68) (Table 3); as fruit diameter increases, fruit height also increases (Table 3).

Fruit diameter had a very significant difference, as GoldSUB (12.60 cm) and AlphaSOIL (12.75 cm) had fruit diameter longer than the others while SinSOIL (6.10 cm) was shortest (Table 2). Drip irrigation substrate culture system gave fruit diameter of 11.30-12.75 cm which was observably higher than in NFT hydroponic system with 9.30-10.60 cm, and drip irrigation soil culture system of 6.10-10.50 cm (Table 2).

Plant height had a very significant difference as GoldSUB (230.20 cm) had the tallest plants as compared with the rest. In general, drip irrigation substrate culture system gave the plant height observably higher than in NFT hydroponic system, and drip irrigation soil culture system (Table 2). Plant height was positively associated with fruit diameter (r = 0.52), fruit height (r =0.50), flesh thickness (r = 0.29), TSSC (r = 0.11), fruit weight (r = 0.59), and yield (0.59) (Table 3). This means that as plant height increases, fruit diameter, fruit height, flesh thickness, TSSC, fruit weight, and yield also increase.

Table 2. Yield, fruit weight, fruit number, total soluble solids content (TSSC), flesh thickness, fruit height, fruit diameter, and plant height of four cantaloupe varieties grown in NFT hydroponic system and drip irrigation systems of substrate and soil culture in Chanthaburi, Thailand

Variety and planting system	Yield (t ha^{-1})	Fruit weight (kg $fruit^{-1}$)	Fruit number (fruits ha^{-1})	TSSC (% brix)	Flesh thickness (cm)	Fruit height (cm)	Fruit diameter (cm)	Plant height (cm)
AlphaNFT	13.52ab	0.70ab	19,313.00	12.30a	2.85ab	9.75def	10.60ab	132.25c
EmeraldNFT	14.09ab	0.73ab	19,313.00	15.68a	3.30ab	10.58def	10.38ab	127.03c
SinNFT	11.59ab	0.60ab	19,313.00	12.00ab	2.45bc	12.30cd	9.30abc	120.00c
AlphaSUB	23.18a	1.20a	19,313.00	11.90ab	3.73a	12.00cde	12.75a	195.40ab
EmeraldSUB	23.18a	1.20a	19,313.00	8.88abc	3.63a	13.50bc	12.18ab	112.68c
SinSUB	23.18a	1.20a	19,313.00	12.73a	3.38ab	16.83a	11.30ab	162.57bc
GoldSUB	24.14a	1.25a	19,313.00	11.60abc	2.95ab	15.10ab	12.60a	230.20a
AlphaSOIL	12.55ab	0.65ab	19,313.00	13.90a	2.75abc	9.50ef	10.50ab	117.00c
EmeraldSOIL	7.73b	0.40b	19,313.00	4.95bc	2.23bc	8.10f	8.38bc	138.50bc
SinSOIL	4.44b	0.23b	19,313.00	4.40c	1.63c	8.18f	6.10c	127.32c
C.V. (%)	30.66	30.66	-	23.00	13.97	8.26	13.79	14.47

Table 3. Relationships of yield, fruit weight, total soluble solids content (TSSC), flesh thickness, fruit height, fruit diameter and plant height of cantaloupes

Plant Parameter	Yield	Fruit Weight	TSSC	Flesh Thickness	Fruit Height	Fruit diameter
Fruit weight	r=1.00	-	-	-	-	-
TSSC	r=0.45	r=0.45	-	-	-	-
Flesh thickness	r=0.87	r=0.87	r=0.61	-	-	-
Fruit height	r=0.85	r=0.85	r=0.40	r=0.62	-	-
Fruit diameter	r=0.93	r=0.93	r=0.60	r=0.90	r=0.68	-
Plant height	r=0.59	r=0.59	r=0.11	r=0.29	r=0.50	r=0.52

r is a correlation coefficient.

Discussion

An average yield and fruit weight of cantaloupe production in NFT hydroponic system were appreciably higher than that in drip irrigation soil culture system by about 66% and 65%, respectively. The results agreed with Singer *et al.* (2013) who reported that NFT hydroponic system gave a better yield and higher fruit quality (flesh firmness, flesh thickness, fruit diameter, fruit weight), and better growth (in terms of plant height, number of leaves, and leaf area) compared with that in a soil culture. The results also agreed with Gysi and Von Allmen (1997) who reported that the tomato culture in NFT hydroponic system gave higher yield than that in soil culture. With these results, Abed El-Rahman *et al.* (2003) and Singer *et al.* (2009) cited that each fruit mostly increases its weight by absorbing more water resulting in an increased fruit weight. In addition, El-Behairy (2003), Fer ñandez-Trujillo *et al.* (2004), Natalini *et al.* (2007) and Singer *et al.* (2012) articulated that NFT hydroponic system helps in promoting the growth of cantaloupe plants better than that in soil culture. The results agreed with Singer *et al.* (2013) who reported that NFT hydroponic system promoted a better plant growth as a result of giving the nutrient solution to the plants. With this reason, the plants' roots could directly uptake the nitrogen ion for its growth, and consequently a better plant growth then prompting a yield increase. Bish *et al.* (1997), Hennion *et al.* (1997) and El-Behairy (2008) described that the bigger plant stem means the higher yield is obtained, as there is more leaf area to intercept more light (to have more photosynthesis to produce more assimilates) resulted in a high yield. AlphaNFT, EmeraldNFT, and SinNFT gave yield and fruit weight noticeably higher than AlphaSOIL, EmeraldSOIL and SinSOIL. The results agreed with El-Behairy *et al.* (2001) and Singer *et al.* (2009 and 2012) who reported the result on cantaloupe, Abou-Hadid *et al.* (1989) and Rumple *et al.* (1996) on tomato, Al-Harbi *et al.* (1996) on cucumber, and El-Shinawy and Gawish (2006) on lettuce. These authors cited that the plants grown in NFT hydroponic system gave a better growth, high yield and high fruit quality compared with the plants grown in the soil.

However, the average yield of the cantaloupe production in drip irrigation substrate culture system was higher than those in NFT hydroponic system and drip irrigation soil culture system by about 71% and 184%, respectively. The average fruit weight in drip irrigation substrate culture system was likewise heavier than those in NFT hydroponic system and drip irrigation soil culture system by about 70% and 181%, respectively. AlphaSUB, EmeraldSUB, SinSUB and GoldSUB gave yield and fruit weight apparently higher than AlphaNFT, EmeraldNFT, SinNFT, AlphaSOIL, EmeraldSOIL and SinSOIL.

These were mainly due to having a positive relationship with the flesh thickness, fruit height, and fruit diameter in the drip irrigation substrate culture system. GoldSUB plants were the tallest compared with the other cantaloupe varieties together with the planting systems. The tall plant (or long stem) is one of the good plant characteristics contributed to better light interception for photosynthesis resulted in a high assimilate production. GoldSUB plants were also observed to have the biggest stems. The results agreed with Wiangsamut *et al.* (2016) who reported that the bigger tillers of rice genotypes had more assimilate accumulation in the stems and assimilates partitioning for grains at maturity. Consequently, there was higher filled grain weight per panicle and higher filled grain number per panicle for SL-8 (hybrid rice). Thus, Golden Lady 1382 grown in drip irrigation substrate culture system (GoldSUB) had the heaviest fruit weight and the highest yield and good fruit quality in terms of total soluble solids content (TSSC).

Runoff water could be a pathway of nutrients loss in drip irrigation soil culture system plot, although it had more nutrients applied to the plants than NFT hydroponic system and drip irrigation substrate culture system plot for an entire growing period (Table 1). The main loss of nutrients could also be due to the rain during the early raining season (April to July of 2016), as it was tested under the open field cultivation. Santasap (2009) reported that applying the fertilizer to the plants could cause the loss of some nutrients through the soils, and some were available in the soils accounted by 70% availale N, 30% available P, and 70% available K. While the NFT hydroponic system and the drip irrigation substrate culture system plots were tested in protected cultivation to prevent from the rain. The loss of nutrients in hydroponic system and drip irrigation substrate culture system plots were in negligible amount, as the plants were grown in NFT hydroponic tables and in substrate medium that was placed above the black plastic sheet to prevent the loss of water and nutrients, respectively. Morever, the total nutrients available to the cantaloupe plants in drip irrigation substrate culture system plots were higher than those plants in NFT hydroponic tables for entried crop duration (Table 1). With these evidences, there was adequate supply of nutrients to the cantaloupe plants in drip irrigation substrate culture system as compared with those plants in NFT hydroponic system and drip irrigation soil culture system. An adequate nutrient uptake on the plants resulted in a better plant growth, high yield, and high fruit quality.

Conclusion

Yields of 4 cantaloupe varieties (Alpha TA209, Emerald Sweet 1225, Golden Lady 1382, and Sin Jiang TA212) could be best grown in drip irrigation substrate culture system rather than in NFT hydroponic system and drip irrigation soil culture system attributable to better fruit weight, flesh thickness, fruit height, and fruit diameter. These fruit quality parameters were positively associated with yield. Plant height was also positively associated with yield and fruit weight. Golden Lady 1382 in drip irrigation subtrate culture system had the tallest plants, the highest yield at 24.14 t ha^{-1}, the heaviest fruit weight at 1.25 kg $fruit^{-1}$, and high total soluble solids content (TSSC) at 11.60% brix compared with the rest. In general, plant height was the tallest in drip irrigation substrate culture system compared with those plants in drip irrigation soil culture system and in NFT hydroponic system. Most of cantaloupe varieties had high TSSC observed in the three planting systems except EmeraldSOIL and SinSOIL.

Recommendations

Based on the results, it is recommended that the best cantaloupe planting system was drip irrigation substrate culture system. This planting system could be adopted by the farmers in the province of Chanthaburi, Thailand rather than the usual drip irrigation soil culture system and the NFT hydroponic system.

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