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Characteristics of Domestic Net Type Melon in Hydroponic Spring Cultivars Using Coir Substrates

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Abstract

Hydroponics is considered to be useful for crop growth and quality control due to precision in nutrient supply and water management. This study investigated the adaptation of a hydroponic system on a coir substrate for spring season melon cultivars. Thirteen netted domestic cultivars grown in the spring season were evaluated in a Venlo glass greenhouse. Among the 13 cultivars, 'Santafe', 'PMR Dalgona', 'Earl's Miracle', 'Earl's Crown', and 'Hero' showed soluble solids content (SSC) of 12.0–15.5°Brix, higher than that of 'Earl's Prugio', 'Earl's Kingstar', and 'Fantasy'. At the harvest stage, plant length was longer in 'Earl's Kingstar', 'Earl's Fantasy', 'Earl's Crown', 'Santafe', and 'Earl's Aibi' than in the other cultivars, and leaf length was longer in 'Earl's Kingstar', 'Earl's Prugio', 'Santafe', 'Earl's Fantasy', and 'PMR Dalgona'. Fruit weight was highest in 'Earl's Kingstar' (2.46 kg) and lowest in 'Santafe' (1.59 kg), while the other cultivars including 'Earl's Aibi' had almost 2 kg weight. There was a negative correlation between fruit weight and sugar content. The results from this experiment may be useful for adaptability tests of domestic cultivars grown hydroponically using coir substrates. Ultimately, this study will be used as the basis for selecting a cultivar suitable for the export market, determining plant spacing, and establishing quality stabilization for melon hydroponics.

Additional key words: fruit weight, leaf length, plant length, soluble solids content (SSC)

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Introduction

Melon (*Cucumis melo* L.) has attracted a wide range of consumers because of its flavor. It is a promising export crop, but is often neglected by consumers due to the absence of a steady supply of quality fruit in the market. This often results from melon diseases such as fusarium wilt, monosporascus root rot, phytophthora rot, and nematodes transmitted through roots. Once introduced into soil or medium, the pathogens incessantly survive and cause continuous cropping obstacles and serious yield losses (Banihashemi et al., 1975; Lee et al., 2015). To overcome these problems and achieve reliable production, an isolated bench cultivation was attempted (Cho et al., 1999a; Shin et al., 2011), but the supply to the farmhouse was very limited because of excessive requirements of bed soil and

the inconvenience of installing the isolated bench.

Hydroponic culture systems allows precise management of water and nutrient solutions, which facilitates crop growth, quality control, and labor savings (Hwang et al., 1998; Li et al., 2001; Chang et al., 2012; Park et al., 2016; Nam et al., 2019). With the increased demand on farmers for productivity improvements and a government project for modernization of facilities that began in 1992, the overall area of hydroponic cultures has increased to 4,205 ha (7.8% of total acreage) by 2017 from just 94 ha in 1994. Moreover, the hydroponics area is expected to continue increasing because of improvements in the cultivation system, such as in materials and equipment; however, the cultivation area of hydroponically-cultivated melon is still only 0.5% of the total melon area, which is related to a lack of cultivation technology and the high costs of installing and operating a hydroponic system. Therefore, more studies for stable high-quality melon production by hydroponics are needed. Plant growth in hydroponics varies depending on the type of hydroponic system, the medium, and nutrient solution control methods (Son and Park, 1998; Kim and Chang, 2004). Of the solid media being used currently for hydroponics, which includes perlite, rock wool, coir, peat moss, and mixture medium, the use of coir substrates is increasing due to readily available supply, fewer environmental problems in disposal after use or during handling, competitive pricing, and ease of installation (An et al., 2009). In 2017, use areas of coir greatly overtook those of perlite or rock wool and increased to 69.5% of the total solid media in the hydroponic cultivation of strawberry (MAFRA, 2018).

Use of coir has many agricultural advantages because of its stable physical and chemical properties, which provide high water holding capacity, high water permeability, high porosity in medium, high cation exchange capacity (CEC), significant amounts of phosphorous and potassium, and an ideal pH range that is slightly acidic, while coir medium has a high content of Na and Cl and a low content of N, Ca, Mg, and micronutrients (Vavrina et al., 1996; Fascella and Zizzo, 2005; Rincon et al., 2005; Choi et al., 2016). Moreover, moisture variation in coir medium does not significantly influence chemical changes in root zones, thereby enabling stable crop productivity (Hellemans, 2006; Shin and Son 2015; Choi et al., 2019).

Melon has a short growth period and can be grown up to four times a year (Cha et al., 2013; Lee et al., 2015). There are great differences in the quality of melon fruit caused by interseasonal variations in growing conditions with low temperature and less sunlight in winter and high temperature and humidity in summer (Sin et al., 1991; Nishizawa et al., 2000; Lee, 2002). Therefore, for the purpose of reliable and steady production of high sugar content and superior quality melon irrespective of the culture environment, more research is needed to develop diverse cropping systems and cultivars in hydroponics systems and to increase the marketable quality of melon.

In addition, melon hydroponics is based on vertical growing to increase the use of space in the cultivation facility; therefore, plant height should be considered in relation to vine training, thinning, pinching, and other farming processes. The thinning region at the highest position in the plant directly affects work intensity and fatigue, and the cultivar's own plant height may also be an important factor. Ben-Oliel and Kafkafi (2002) have been trying to develop a short-node cultivar through melon breeding to reduce the harvest period to a minimum and to maintain the greenhouse plants in good condition.

This study aimed at examining the adaptability of coir medium in melon hydroponics using coir substrates by examining the growth characteristics of cultivars suitable for hydroponics in spring culture.

Materials and Methods

Experimental Design and Growth Control

The experiment was conducted in a Venlo glass greenhouse (672 m^2) at the Protected Horticulture Research Institute, NIHHS, RDA, Haman, Korea. Thirteen spring cultivars of commercial netted melon were used (Table 1). On 1 February 2018, seeds of the 13 cultivars were sown in 50-plug trays filled with a soil mix for nursery beds, and seedlings were transplanted into the beds in the greenhouse on 12 March 2018. Coir slab (Dae Young GS, Korea) was prepared with a size of 100 cm (L) × 20 cm (W) × 10 cm (D) at a ratio of 30% coir chip and 70% dust, and plant spacing was 33.3 cm (3 plants per slab) between plants and 150 cm between rows. This experiment was arranged in a randomized block design with three replications for each cultivar and with 12 treatments for each replication (13 cultivars × 3 replications × 4 slab × 3 plants = 468 plants). Yamazaki standard nutrient solutions (Yamazaki, 1982) for melon were supplied with 1.8, 2.0, and 2.3 $dS \cdot m^{-1}$ electric conductivity (EC) at the early, middle (fruit enlargement), and late growth stages, respectively. The drainage ratio at each growth step was managed at 20, 30, and 10%. Temperature was maintained at 30/16°C day/night in a greenhouse. Plants were pollinated by bumble bees inside the greenhouse on 16 April 2018. Fruit thinning

Table 1. Commercial melon cultivars used in this experiment

No.	Cultivars	Application Number	Maturity days	Seed companies
1	PMR Dalgona	2015 - 1641[z]	50	Lucky Seeds
2	Earl's Aibi	2012 - 846	53 - 55	Lucky Seeds
3	Earl's Orora	2012 - 1267	55 - 60	Lucky Seeds
4	Earl's Prugio	2012 - 1266	55	Lucky Seeds
5	Earl's Miracle	2012 - 1262	55 - 60	Lucky Seeds
6	Earl's Fantasy	2004 - 876	55 - 60	Lucky Seeds
7	PMR Royal honey	2016 - 1307	53 - 55	Lucky Seeds
8	Hero	2013 - 1664	50 - 55	Farm Hannong Co., Ltd.
9	Earl's Crown	2015 - 1900	58	Nongwoobio Co., Ltd.
10	Earl's Kingstar	2003 - 1736	55	Nongwoobio Co., Ltd.
11	Earl's Impact	2008 - 262	55	Nongwoobio Co., Ltd.
12	Aslan PMR	2015 - 93	55	Asia Seed Co., Ltd.
13	Santafe	2015 - 114	55	Asia Seed Co., Ltd.

[z]KOREA SEED & VARIETY SERVICE (2019) Publication of application http://www.seed.go.kr/seed_eng/951/subview.do

Fig. 1. Photographs of different stages of muskmelon (A) early planting, (B) pinching, (C) fruiting.

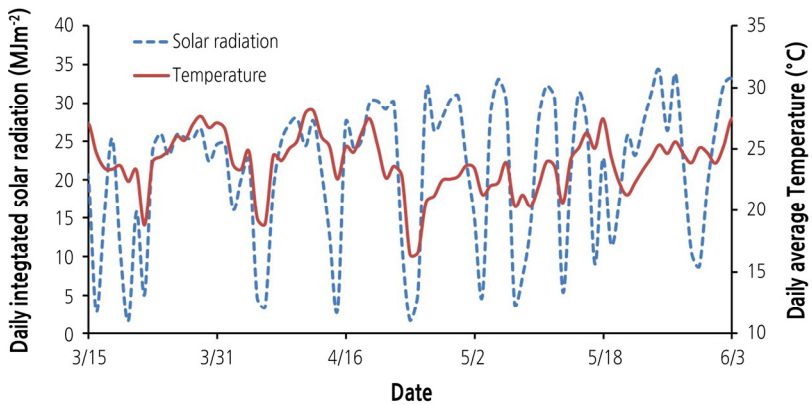

Fig. 2. Daily average temperature and integrated solar radiation measured during the experimental period.

was conducted selectively leaving one fruit with pinching at the 22nd and 23rd nodes on 19 April 2018 after fruit setting between the 11st and 13rd nodes. Fruits were harvested between days 55 – 60 after fruit set in accordance with the maturity of each cultivar (Fig. 1). In the spring season, daily average temperature and daily integrated solar radiation was measured during the experiment period (Fig. 2).

Analysis of Growth and Fruit Characteristics

For plant characteristics, plant length, leaf length, leaf width, petiole length, and leaf area, and for fruit properties, fruit weight, fruit diameter, fruit height, flesh thickness, sugar content, and net index were measured, respectively. For soluble solids content (SSC), three pulp samples (3 replications × 5 treatments, 15 total samples) were taken from the equatorial slice and mixed in a blender, and then SSC was measured from juice extracted from the three samples with a refractometer (PAL-1, Atago Co. Ltd., Tokyo, Japan) and expressed as °Brix (Lee and Kim, 2003).

Data Analysis

The data of this experiment was analyzed using SAS system (Version 9.4, SAS Inc., USA). Statistical analysis of all data was performed using one-way analysis of variance (ANOVA), and subsequent comparisons among melon cultivars with Duncan's multiple range test at the $p < 0.05$ level of significance.

Results and Discussion

In the study of growth characteristics of the 13 cultivars, 'PMR Dalgona' showed the shortest plant length from the soil surface up to the 10th node (30.6 cm) and up to the 20th node (94.1 cm). 'Earl's Kingstar' had the longest plant length at both the 10th node (43.0 cm) and 20th node (134.6 cm). It also showed the highest leaf length (21.7 cm) and width (31.3 cm) (Table 2).

Melon fruit quality depends mainly on fruit size, sugar content, firmness, flavor, and net stability. Among these qualities, sugar content is known to play the most important role in determining the quality of melon fruit (Kim et al., 2007). For the sugar content or the soluble solids content (SSC, °Brix) of the 13 cultivars tested, 'Santafe' had the highest

Table 2. Growth characteristics of 13 muskmelon cultivars in spring season

Cultivars	Height (cm)		Leaf length (cm)	Leaf wide (cm)	Petiole (cm)	Leaf area[z] (cm^2)
	10th node	20th node				
PMR Dalgona	30.6 d[y]	94.1 f	20.3 bc	26.7 f	15.3 h	435.2 ef
Earl's Aibi	35.2 c	112.1 cd	19.1 ef	26.9 f	18.7 ab	417.6 fg
Earl's Orora	35.9 c	105.7 e	19.8 cde	29.0 cd	19.2 a	470.5 cd
Earl's Prugio	31.6 d	95.8 f	21.3 ab	28.3 de	18.7 ab	479.5 b-d
Earl's Miracle	31.6 d	98.8 f	19.1 ef	25.4 g	16.9 b-d	390.6 g
Earl's Fantasy	40.0 b	119.7 b	20.0 cd	28.4 d	18.3 b-d	461.4 de
PMR Royal honey	33.4 cd	98.2 f	19.5 de	27.4 ef	17.0 fg	433.4 ef
Hero	33.5 cd	104.6 e	20.0 cd	27.0 f	16.5 g	436.2 ef
Earl's Crown	39.6 b	118.7 b	20.4 bc	29.5 bc	17.5 d-f	493.1 bc
Earl's Kingstar	43.0 a	134.6 a	21.7 a	31.3 a	17.6 c-f	554.4 a
Earl's Impact	33.2 cd	97.6 f	20.1 cd	28.7 cd	17.4 ef	471.8 cd
Aslan PMR	36.2 c	110.8 d	18.6 f	26.4 f	18.3 bc	400.1 g
Santafe	35.6 c	116.8 bc	20.5 bc	30.1 b	17.9 b-e	505.0 b
F-test	***	***	***	***	***	***

The values of growth characteristics are represented as averages of 15 samples (3 replications x 5 treatments).
[z]Equation; πR^2, R= {(leaf length + leaf width)/2}/2.
[y]Mean separation within columns by Duncan's multiple range test ($p \leq 0.05$).
***; Significant at $p < 0.001$.

value with 15.5°Brix, while 'Earl's Aibi' and 'Earl's Kingstar' had the lowest values (–10.7°Brix) (Table 3).

The highest and lowest fruit weights were found in 'Earl's Kingstar' (2.46 kg) and 'Santafe' (1.59 kg), respectively. Furthermore, 'Santafe' also showed the lowest values for fruit height and fruit width (Table 3 and Fig. 3). The study on the relationship between fruit size and sugar content indicated a highly negative correlation (Fig. 4), which was similar to previous reports by Chang et al. (2012).

Hydration can be easily controlled with solid medium more so than for water cultures. Therefore, solid medium is suitable for culturing aimed at high-sugar fruit production. However, the response or output of solid culture varies with the type of media (Schiavi et al., 1995; Kim and Chang, 2004). From the results of this study, the melon fruit weight in coir medium hydroponics showed a tendency similar to perlite or rockwool hydroponics; the fruit weight of muskmelon was about 1.6–1.5 kg in perlite hydroponics (Cho et al., 1999b), and about 1.9–1.8 kg in rockwool hydroponics (Chang et al, 2012). The average fruit weight in this study was about 2 kg, which met the domestic standard of 1.8–2.0 kg (Hwang, 1999; Kim and Chang, 2004; Chang et al., 2012). Therefore, coir medium may be considered suitable for melon hydroponics. There have been many studies on the validity of coir substrates in tomato long-term hydroponics, in comparison to rock wool medium, and recent work has shown that coir medium enables reliable plant production as it does not significantly affect the chemical properties of root substrates (Hellemans, 2006; Kim et al., 2008; Shin and Son, 2015; Choi et al., 2017).

Table 3. Fruit characteristics of 13 muskmelon cultivars in spring season

Cultivars	Fruit weight (kg/fruit)	Fruit length (cm)	Fruit diameter (cm)	Fruit shape index	Fresh thickness (mm)	Soluble solids content (°Brix)	Net index[z] (1 – 5)
PMR Dalgona	1.89 f[y]	15.1 e	15.0 e	1.00 d	47.6 d-f	12.6 b	1.2
Earl's Aibi	2.40 ab	17.3 a	16.4 a	1.05 ab	50.6 bc	10.7 g	1.6
Earl's Orora	2.32 bc	17.0 bc	15.9 c	1.07 a	46.6 ef	11.2 ef	2.2
Earl's Prugio	2.40 ab	16.8 c	16.3 ab	1.02 cd	50.1 b-d	10.9 fg	2.0
Earl's Miracle	2.09 e	15.9 d	15.4 d	1.03 bc	49.2 c-e	12.2 bc	1.8
Earl's Fantasy	2.39 ab	17.0 a-c	16.2 a-c	1.06 a	49.5 cd	9.4 h	1.6
PMR Royal honey	2.25 cd	16.1 d	15.9 c	1.01 cd	52.1 ab	11.6 de	2.2
Hero	2.07 e	16.1 d	15.2 e	1.06 a	46.4 fg	12.0 cd	1.4
Earl's Crown	2.38 ab	17.2 ab	16.1 bc	1.06 a	53.3 a	12.1 c	2.2
Earl's Kingstar	2.46 a	17.2 ab	16.4 a	1.05 ab	48.2 c-f	10.8 fg	1.8
Earl's Impact	2.15 de	16.1 d	15.6 d	1.02 cd	49.1 c-e	11.6 de	1.8
Aslan PMR	2.35 b	17.1 ab	16.1 bc	1.07 a	50.1 b-d	11.4 e	2.4
Santafe	1.59 g	14.5 f	13.8 f	1.06 a	43.8 g	15.5 a	2.2
F-test	***	***	***	***	***	***	-

The values of fruit characteristics are represented as averages of 30 samples (3 replications x 10 treatments).

[z]1, excellent; 2, good; 3, average; 4, poor; 5, bad

[y]Mean separation within columns by Duncan's multiple range test ($p \leq 0.05$).

***; Significant at $p < 0.001$.

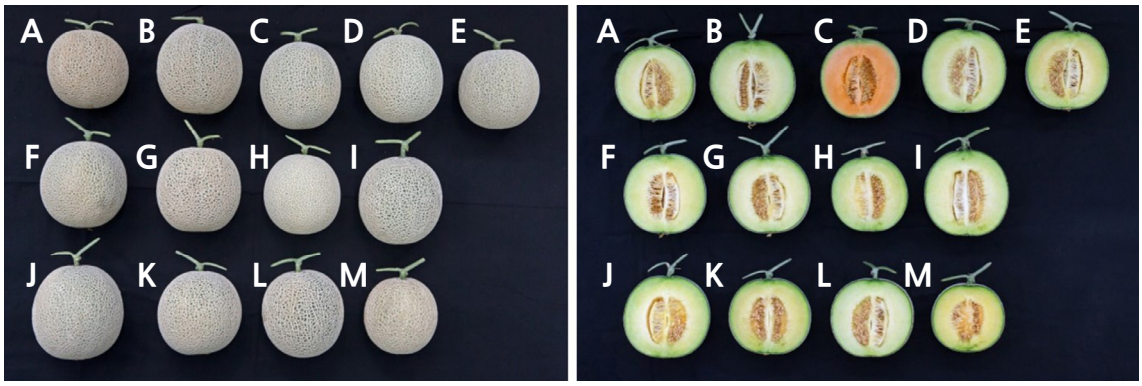

Fig. 3. Photographs of fruit shape (left) and flesh (right) of 13 domestic net-type cultivars in hydroponics using coir substrates: PMR Dalgona (A), Earl's Aibi (B), Earl's Orora (C), Earl's Prugio (D), Earl's Miracle (E), Earl's Fantasy (F), PMR Royal honey (G), Hero (H), Earl's Crown (I), Earl's Kingstar (J), Earl's Impact (K), Aslan PMR (L), Santafe (M).

On the basis of node length and plant height as measured in this experiment, the 13 cultivars were classified into 3 or 4 groups (Table 4). Five short cultivars including 'PMR Dalgona' were in a group of plants with heights under 120 cm, seven cultivars including 'Earl's Aibi' were in a group with heights between 120 cm and 140 cm, and one cultivar ('Earl's Kingstar'), which was in its own group, had a height above 140 cm.

In terms of leaf area, 'Earl's Kingstar', 'Earl's Prugio', 'Santafe', 'Earl's Fantasy', and 'PMR Dalgona' were part of the large group (Table 4). Leaf area is the main factor influencing planting distance and can be a major consideration for

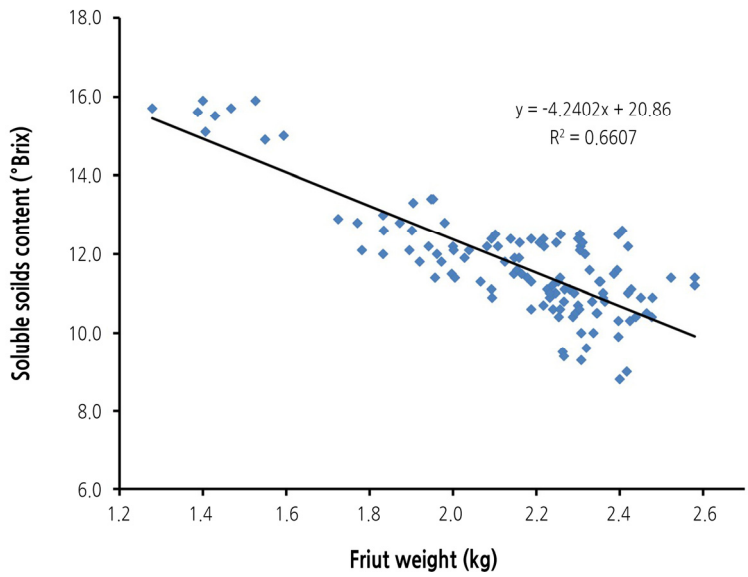

Fig. 4. Correlation between fruit weight and soluble solids content.

cultivar selection in hydroponics along with plant height. Hwang et al. (1998) reported that a wide planting distance in hydroponic culture resulted in more marketable fruit yields, although the total yields decreased, while a narrow planting distance decreased fruit weight and sugar content. Thus, leaf area is an important factor for planting distance and plant height studies.

For fruit weight, 9 cultivars including ‘Earl’s Kingstar’ were classified in the group above 2 kg, 3 cultivars (‘PMR Dalgona’, ‘Earl’s Miracle’, and ‘Hero’) were in the group of 1.8 – 2.1 kg, and ‘Santafe’ was in the group of 1.4 – 1.7 kg, with no cultivar under 1.4 kg. In the analysis of SSC, ‘Santafe’, ‘PMR Dalgona’, ‘Earl’s Miracle’, ‘Earl’s Crown’, and ‘Hero’ had high values of 15.5 – 12.0°Brix. In contrast, ‘Earl’s Prugio’, ‘Earl’s Kingstar’, ‘Earl’s Aibi’, and ‘Earl’s Fantasy’ had relatively low values among the 13 cultivars. Also, there was a negative correlation between fruit weight and SSC. In principle, the accumulation of soluble sugars in fruit is a combination of growing conditions and genetic factors; however, because this type of cultivar comparison test was conducted under the same (batch) culture conditions, the possible exclusion of each cultivar's own genetic factors should be considered. In the future, more investigations are needed to better control irrigation during the fruit enlargement stage, to more accurately estimate planting distance, and to identify the optimal balance between fruit weight and sugar content for each cultivar.

Among the 13 net type and domestic cultivars used in this study, ‘Earl’s Miracle’ was in the following groups: high sugar content in spring culture, middle fruit weight, and low plant height and leaf area. Such characteristics of ‘Earl’s Miracle’ suggest the possibility of increasing plant density and reducing labor costs (Table 4). However, we should also consider the possibility of genetic factors inherent in each cultivar, which was excluded in this study since the comparison test was conducted in batches under the same culture conditions, as sugar accumulation in fruits depends on a combination of environmental and genetic factors (Kim et al., 2007).

The results of this study establish a basis for the selection of adaptable melon cultivars in hydroponics using coir substrates and for the control of planting spacing and fruit set node. Ultimately, this study provides useful information for establishing a year-round production system and for quality stabilization in melon hydroponics.

Table 4. Classification of 13 muskmelon cultivars by height, leaf area, fruit weight, and soluble solids content

Category	Range	No. of cultivars	Name of cultivar
Height (cm)	> 140	1	Earl's Kingstar
	120 – 140	7	Earl's Aibi, Earl's Orora, Earl's Fantasy, Hero, Earl's Crown, Aslan PMR, Santafe
	< 120	5	PMR Dalgona, Earl's Prugio, Earl's Miracle, PMR Royal honey, Earl's Impact
Leaf area (cm^2)	> 500	2	Santafe, Earl's Kingstar
	400 – 500	10	Earl's Aibi, PMR Royal honey, PMR Dalgona, Hero, Earl's Fantasy, Earl's Orora, Earl's Impact, Earl's Crown, Aslan PMR, Earl's Prugio
	< 400	1	Earl's Miracle
Fruit weight (kg/fruit)	> 2.1	9	Earl's Kingstar, Earl's Aibi, Earl's Prugio, Earl's Fantasy, Earl's Crown, Aslan PMR, Earl's Orora, PMR Royal honey, Earl's Impact
	1.8 – 2.1	3	Earl's Miracle, Hero, PMR Dalgona
	1.4 – 1.7	1	Santafe
	< 1.4	0	-
Soluble solids content (°Brix)	> 12	4	Santafe, PMR Dalgona, Earl's Miracle, Earl's Crown
	10 – 12	8	Hero, Earl's Impact, PMR Royal honey, Aslan PMR, Earl's Orora, Earl's Prugio, Earl's Kingstar, Earl's Aibi
	< 10	1	Earl's Fantasy

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