Selection of potential genotypes and traits evaluation of honeydew (*Cucumis melo* L.)

B A Iskandar¹*, W B Suwarno¹,², E Gunawan², and S K Saptomo³

¹ Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University, Jl. Meranti Kampus IPB Dramaga, Bogor 16680, Indonesia
² Center for Tropical Horticulture Studies, Institute of Research and Community Development (LPPM), IPB University, Jl. Raya Pajajaran Kampus IPB Baranangsiang, Bogor 16141, Indonesia
³ Department of Civil and Environmental Engineering, Faculty of Agricultural Technology, IPB University, Gedung Fateta Kampus IPB Darmaga, Bogor 16680, Indonesia.

*Corresponding author: bunga.aprini@gmail.com

Abstract. Quality improvements of honeydew (*Cucumis melo* L.) can be carried out by developing new superior hybrid varieties. This study aimed to identify potential genotypes having good fruit quality for breeding improved hybrid honeydew varieties. The experiment was conducted from March to May 2019 at the Tajur II experimental station of PKHT, IPB University, Bogor. The experiment was arranged in a single-factor randomized complete block design with three replicates. There were six test genotypes from S2 generation, namely IPB HD1, IPB HD2, IPB HD3, IPB HD4, IPB HD5, IPB HD6; three inbred lines, namely SMM, SMF, and OMM; and also one check variety (Alisha F1). The results indicated that genotypes had significant effects on all observed quantitative characters, namely leaf width, leaf length, stem diameter, internode length, days to harvest, fruit length, fruit weight, and total soluble solids. The SMM genotype had the highest average fruit weight as well as the other characters, i.e. leaf width, leaf length, stem diameter, and fruit length. There were also IPB HD1 and HD4 having the highest average of flesh thickness and sugar content, respectively. These three genotypes are predicted to have good potential for developing improved hybrid honeydew varieties.

Keywords: genetic diversity, fruit quality, melon breeding

1. Introduction
Honeydew (*Cucumis melo* L.) is a nutritious fruit and popular in many countries, including Indonesia. Honeydew contains 92% water; 1.5% protein; 0.3% fat; 6.2% carbohydrate; 0.5% fiber; and 357 IU of Vitamin A [1]. Honeydew is a healthful food choice as it is rich in ascorbic acid, β-carotene, folic acid, potassium, as well as another bioactive compound [2].

Consumer preferences for a good honeydew determined by the sugar content, taste or flavor, fruit texture, and nutrition content [3]. This indicates that fruit quality is important. The quality of fruit products can be divided into two, external quality which is fruit appearance, and internal quality which is taste and nutrition [4]. Both are important factors affecting the price and customers’ decision about buying products.
One important problem is the availability of domestic superior varieties. This limits the variability of honeydew fruit types in the market, as well as encourages seed imports. Imported honeydew varieties may not suitably adapt with the environmental conditions at the production centers in Indonesia. Additionally, the continuous supply of imported seed cannot be guaranteed, and the price of imported seeds is unfortunately expensive [5].

Quality improvements can be carried out by developing improved hybrid varieties. Hybrid varieties have both quality and uniformity traits which benefit the farmers and consumers. At the same time, the seed industries also get a benefit as the farmers would require to buy hybrid seeds every planting time. If the seed is replanted, the uniformity of the fruits, as well as the plants’ resistance to pest and diseases, will be altered because of genetic segregation. Breeding improved honeydew varieties is potential because the genetic diversity of melon is large [6]. Developed varieties are expected to reduce imported seed and increase the variability of superior varieties in the market. The challenge is producing high quality of domestic honeydew varieties that can compete with imported qualities. With that, this study aimed to identify potential genotypes having good fruit quality for breeding improved hybrid honeydew varieties.

2. Materials and Methods

The experiment was conducted from March to May 2019 at the Tajur II experimental station of PKHT, IPB University, Bogor. There were six test genotypes from S2 generation, namely IPB HD1, IPB HD2, IPB HD3, IPB HD4, IPB HD5, and IPB HD6; three inbred lines, namely SMM, SMF, and OMM; and one check variety (Alisha F1). The experiment was arranged in a single-factor randomized complete block design with three replicates.

The experiment began with land clearing. Soil tillage was conducted, and manure and chemical fertilizers were applied. Fertilizer doses were 1 kg of manure, 25 g Urea, 30 g KCl, and 20 g TSP per plant. Additionally, 250 g of CaCO$_3$ per square meter was applied. The beds were made of 50 cm high and covered with plastic mulch. The seedlings were planted 15 days after nursery. Plant spacing was 60 cm x 60 cm.

Plants were maintained includes watering, binding of plants and fruit, lateral pruning except for the 8$^{th}$ to 12$^{th}$ branches, also pests and disease control if needed. Supplementary nutrients of NPK 27:7:7 fertilizers were applied in a solution (5 g l$^{-1}$) at 7, 14, 21 days after planting, also NPK 16:16:16 (10 g l$^{-1}$) at 28, and 35 days after planting. KNO$_3$ fertilizer was applied in a solution (1 g l$^{-1}$) when the fruits were formed.

Morphological traits were observed based on Descriptor for Melon (Cucumis melo L.) [7] with necessary modifications. Quantitative traits observed were: leaf width, leaf length, stem diameter, internode length, days to harvest, fruit length, fruit weight, fruit diameter, flesh thickness, skin thickness, and total soluble solids. Qualitative traits observed including stem color, leaf color, leaf shapes, leaf lobes, leaf glossiness, flower color, fruit shape, unripe and ripe fruit skin color, net presence, groove presence, flesh color, flesh flavor, internal aroma, external aroma, and after taste. Leaf observation was carried out on the leaves in the 8$^{th}$ branch.

3. Result and Discussion

3.1. General Condition

Generally, the condition of the crop was good from the beginning until harvesting time. However, there were several symptoms of diseases detected, including bacterial wilt and Cucumber Mozaic Virus. Additionally, abnormal plants were also found. Some pests were also identified, i.e. grasshopper, red bugs, and Aulocophora sp in low intensity intrusion. Aulocophora sp. attacks every stage of cucurbits; it fed under cotyledon by biting holes [8]. Fruit flies (Bactrocera dorsalis) identified with medium to high intensity intrusion at fruit development stage. Fruit flies attack was considerably high due to the presence of other vegetable plants such as tomatoes and chili around the experiment area. Pest and disease incursions were controlled by pesticides applications.
3.2. Qualitative Traits

3.2.1. Stem, Leaf, and Flowers Traits

Qualitative traits observed at vegetative stage were stem color, leaf color, leaf shape, leaf lobes, leaf glossiness, and flower color. All observed genotypes possessed the same traits, i.e. green stem color, dark green leaf color, and bright yellow flower color (Figure 1). This shows that these traits cannot be used as markers for differentiating the genotypes. The dark green leaf color indicated that all genotypes grew on an optimum environment with sufficient N nutrient.

![Image](a) Green stem color, (b) Dark green leaf color, and (c) Bright yellow flower color.

The observation results have shown that all genotype had entire leaf shape, but had diversity on leaf lobes (Figure 2). Several genotypes had shallow leaf lobes, namely IPB HD1, HD2, HD4, HD5, HD6, and SMM. While IPB HD3, OMM, SMF, and Alisha F1 had intermediate leaf lobes.

![Image](IPB HD1, IPB HD2, IPB HD3, IPB HD4, IPB HD5, IPB HD6, SMM, OMM, SMF, Alisha F1)

**Figure 2.** The diversity of leaf shapes and leaf lobes on observed genotypes

3.2.2. Fruit Traits

The fruits were developed from manual self- or cross-pollination. The variability of fruit traits from each genotype can be seen in Figure 5. These pictures represent the dominant type of fruits, as there were also segregants within each genotype. The dominant fruit types were determined to be superior in appearance. Mostly inodorus melons have greenish yellow skin, with white or light yellow flesh [9].
The fruit diversity of all observed genotypes

Observed fruit qualitative traits were fruit shapes, unripe and ripe fruit color, flesh color, and flesh texture (Table 1). There was no self-pollinated fruit sample for IPB HD3 genotypes because of the pollination and fruit development failures. The fruit shapes of IPB HD2 and IPB HD6 were round; IPB HD1, HD5, SMM, OMM, and Alisha F1 were flattened; and IPB HD4 and SMF were elliptical.

Mostly, skin color of unripe fruit is greenish and will turn to yellow when the fruit is ripe. However, ripe fruits of IPB HD6 and SMM had a white skin color. Moreover, the flesh color and flesh texture were different among the genotypes. IPB HD1, HD6, and SMF had orange flesh, while IPB HD1, HD4, SMM, and OMM, had white flesh. Meanwhile, IPB HD5 had different flesh color, which is pale green. Nowadays crunchy fruit texture on demand, and we found that five genotypes have crunchy fruit texture, namely IPB HD1, HD2, HD5, OMM, and Alisha F1.

**Table 1.** Fruit shape, unripe and ripe fruit color, flesh color, and flesh texture in several honeydew genotypes

| Genotype | Fruit shapes | Unripe Fruit color | Ripe Fruit color | Flesh color | Flesh texture |
|----------|--------------|--------------------|------------------|-------------|---------------|
| IPB HD1  | Flattened    | Green              | Yellow           | Orange      | Crunchy       |
| IPB HD2  | Round        | Green              | Yellow           | White       | Crunchy       |
| IPB HD3* | -            | -                  | -                | -           | -             |
| IPB HD4  | Elliptical   | Green              | Yellow           | White       | Soft          |
| IPB HD5  | Flattened    | Green              | Yellow           | Pale Green  | Crunchy       |
| IPB HD6  | Round        | White              | Light Yellow     | Green       | Spongy        |
| SMM      | Flattened    | White              | Light Yellow     | White       | Spongy        |
| SMF      | Elliptical   | Green              | Yellow           | Orange      | Soft          |
| OMM      | Flattened    | Green              | Yellow           | White       | Crunchy       |
| Alisha F1| Flattened    | Green              | Yellow           | White-orange| Crunchy       |

*There was no fruit from self-pollination that can be observed.*

The other qualitative fruit traits that observed were external aroma, internal aroma, groove presence, net presence, flesh flavor, and after taste. Honeydew categorized in non-climacteric fruits has smooth skin surface, also lacking of musky odor and flavor [10]. This statement is in agreement with this experiment, which all of the genotypes likely have absent external aroma. Groove and net appeared with low intensity on several genotypes, shown in Table 2. Internal aroma appeared in all observed genotypes.
except IPB HD1 and IPB HD5. Honeydew are common for having sweet, delicately flavored, juicy flesh [9]. Our experiment indicate that all observed genotypes had slightly sweet to sweet flesh with no musky after taste. This indicates that all genotypes have good internal qualities.

**Table 2.** External aroma, internal aroma, groove presence, and net presence, flesh flavor, and after taste in several honeydew genotypes

| Genotype  | External aroma | Groove | Net | Internal aroma | Flesh flavor | After taste |
|-----------|----------------|--------|-----|----------------|-------------|------------|
| IPB HD1   | Absent         | Absent | Absent | Absent | Intermediate | Absent     |
| IPB HD2   | Absent         | Absent | Present | Present | Sweet       | Absent     |
| IPB HD3   | "              | "      | "      | "      | "           | "         |
| IPB HD4   | Present        | Present | Present | Present | Sweet       | Absent     |
| IPB HD5   | Absent         | Present | Present | Absent | Intermediate | Absent     |
| SMM       | Present        | Absent | Absent | Present | Intermediate | Absent     |
| SMF       | Present        | Present | Present | Present | Sweet       | Absent     |
| OMM       | Absent         | Absent | Present | Present | Sweet       | Absent     |
| Alisha F1 | Absent         | Absent | Present | Present | Sweet       | Absent     |

From the observation results of qualitative fruit traits (Table 1 and Table 2), we found that IPB HD1 and IPB HD4 have similarity on several fruit traits with Alisha F1. Furthermore, the fruits from inbred lines, namely SMM, SMF, and OMM, had the same traits as the previous experiment [11]. A previous experiment showed that SMM had white fruit flesh and skin surface, SMF had elliptical fruit shapes and orange colored flesh, while OMM had yellow skin and white colored flesh [11]. These indicate that the fruits were true to type.

### 3.3 Quantitative Traits

Genotypic effects were significant for all observed traits except for fruit diameter, flesh thickness, and skin thickness (Table 3). Meanwhile, the replication did not have significant effects on all observed traits except leaf width traits and stem diameter. Coefficient of variation (CV) of all traits were less than 20%, indicating that the experiment was reliable. The trait with the smallest CV was the day to harvest (2.02 %), and the one with the highest CV was fruit weight (19.49 %).

**Table 3.** Variance analysis recapitulation of quantitative traits in several honeydew genotypes

| Traits                  | Mean square of replication | Mean square of genotypes | Coefficient of variation (%) |
|-------------------------|---------------------------|--------------------------|-------------------------------|
| Leaf width (cm)         | 3.67*                     | 7.35**                   | 4.79                          |
| Leaf length (cm)        | 1.10ns                    | 4.50**                   | 4.97                          |
| Stem diameter (mm)      | 0.60**                    | 0.60**                   | 3.03                          |
| Internode length (cm)   | 0.69ns                    | 3.62**                   | 12.24                         |
| Days to harvest (dap)   | 0.03ns                    | 6.30**                   | 2.02                          |
| Fruit length (cm)       | 2.07ns                    | 5.52**                   | 7.93                          |
| Fruit weight (g)        | 43254.40\text{gs}         | 100198.60*               | 19.49                         |
| Fruit diameter (cm)     | 0.27ns                    | 1.73\text{gs}           | 6.92                          |
| Flesh thickness (cm)    | 0.00\text{ns}            | 0.15\text{ns}          | 9.28                          |
| Skin thickness (cm)     | 0.00\text{ns}            | 0.00\text{ns}          | 17.67                         |
| Total soluble solids (°brix) | 1.90\text{ns} | 5.04**                   | 9.04                          |

* Significant at P < 0.05
** Significant at P < 0.01
\text{ns} Not significant
3.3.1. Stem, Leaf, and Days to Harvest Traits

Genotype means for leaf width, leaf length, stem diameter, internode length, and days to harvest are shown at Table 4. IPB HD1 had the highest average of leaf width (20.6 cm), but not significantly different from IPB HD4 (19.3 cm) and SMM (19.6 cm). The IPB HD4 and SMM had the highest average of leaf length. The highest average on stem diameter was shown by SMM, indicating that SMM had better plant performance than the other genotypes. IPB HD1 and IPB HD2 had significantly longer internode than the others. Genotypes having the shortest average days to harvest were SMM and Alisha F1 (62 days after planting, DAP). This result is different from the last experiment, where SMM had a longer day to harvest (76 DAP) [11], which can be due to the difference in environmental conditions.

Table 4. Mean of quantitative traits: leaf width, leaf length, stem diameter, internode length, and days to harvest

| Genotype | Leaf width (cm) | Leaf length (cm) | Stem diameter (mm) | Internode length (cm) | Days to harvest (DAP) |
|----------|----------------|-----------------|-------------------|----------------------|----------------------|
| IPB HD1  | 20.6a          | 14.0b           | 8.0d              | 9.4a                 | 65abc                |
| IPB HD2  | 17.4b          | 12.9cb          | 8.0d              | 7.0b                 | 64bc                 |
| IPB HD3  | 16.9bc         | 13.8b           | 8.9ab             | 6.4b                 | 66a                  |
| IPB HD4  | 19.3a          | 15.7a           | 8.4cd             | 9.1a                 | 66ab                 |
| IPB HD5  | 17.4b          | 12.3cd          | 8.0d              | 6.6b                 | 65ab                 |
| IPB HD6  | 15.5c          | 11.7d           | 8.7bc             | 6.4b                 | 66ab                 |
| SMM      | 19.6a          | 15.2a           | 9.3a              | 7.5b                 | 62c                  |
| SMF      | 16.9cb         | 13.3eb          | 8.5bcd            | 6.7b                 | 64bc                 |
| OMM      | 16.9cb         | 13.1cb          | 8.8abc            | 6.8b                 | 64ab                 |
| Alisha F1| 17.1cb         | 13.2cb          | 8.0d              | 6.6b                 | 62c                  |

Notes: Means followed by the same letters in the same column are not significantly different based on DMRT at $\alpha = 0.05$

3.3.2. Fruit Traits

Every plant breeding products are expected to comply with the consumers’ demand. Fruit quality is important to be considered when choosing a potential genotype. Many consumers prefer sweet taste, while the farmers also look for a large fruit size. There were no significant difference among genotypes on fruit diameter, flesh thickness, and skin thickness in this experiment. The IPB HD5 had the smallest average of fruit length and weight, 11.8 cm, and 664.3 g respectively (Table 5). The fruits of SMM and SMF were among the longest. The results also showed that SMM did not have a significant difference in fruit weight with SMF, IPB HD1, IPB HD4, and Alisha F1. Fruit sizes and quality are determined by cell enlargement, where cell enlargement is strongly altered by water and nutrients.

The SMM genotype appeared to have similar weight and total soluble solids with the check variety, Alisha F1 (Table 5). The observed genotypes have a range of TSS from 9.3 to 13.7°Brix. This result was considerably good because one suggested that the TSS for commercial honeydew should be equal or higher than 8-10°Brix [12]. IPB HD4 had the highest average TSS, but not significantly different from that of IPB HD2, HD3, HD5, HD5, SMF, and OMM. Sugar content, indicated by total soluble solids, is related to days to harvest [13]. Fruits that are harvested longer tend to have a sweeter taste. The longer the harvest days, the sweeter the fruit gets until reach the limit, which is leading to alcoholic fermentation and then rot.
Table 5. Mean of quantitative traits: fruit length, fruit weight, fruit diameter, flesh thickness, skin thickness, and total soluble solids

| Genotype | Fruit length (cm) | Fruit weight (g) | Fruit diameter (cm) | Flesh thickness (cm) | Skin thickness (cm) | Total soluble solids (°Brix) |
|----------|-------------------|------------------|--------------------|--------------------|-------------------|-----------------------------|
| IPB HD1  | 14.2ab            | 1176.1ab         | 12.8               | 3.2                | 0.1               | 9.3d                        |
| IPB HD2  | 13.2bc            | 887.0bc          | 12.4               | 3.1                | 0.1               | 13.0abc                     |
| IPB HD3  | 14.1ab            | 903.9bc          | 11.9               | 2.9                | 0.1               | 12.3abc                     |
| IPB HD4  | 14.9ab            | 1000.7abc        | 12.3               | 3.0                | 0.1               | 13.7a                       |
| IPB HD5  | 11.8c             | 664.3c           | 10.9               | 2.7                | 0.1               | 12.0abc                     |
| IPB HD6  | 13.0bc            | 897.8bc          | 12.4               | 2.8                | 0.1               | 12.0abc                     |
| SMM      | 16.2a             | 1287.3a          | 13.7               | 3.2                | 0.1               | 11.0cd                      |
| SMF      | 16.0a             | 933.2abc         | 11.7               | 2.7                | 0.1               | 13.0abc                     |
| OMM      | 14.7ab            | 884.0bc          | 12.0               | 2.6                | 0.1               | 13.3ab                      |
| Alisha F1| 14.9ab            | 1167.1ab         | 12.9               | 3.2                | 0.1               | 11.3bc                      |

Notes: Means followed by the same letters in the same column are not significantly different based on DMRT at α = 0.05

3.3 Correlation among Quantitative Traits

Table 6 depicts the correlation coefficients among the observed traits. There were positive correlations between several fruit traits, i.e. fruit length, fruit weight, fruit diameter, and flesh thickness. Fruit weight and flesh thickness were positively related to leaf width, leaf length, and internode length. Total soluble solid had negative, small significant correlation with leaf width, while had no significant correlation with internode length, fruit weight, fruit diameter, and flesh thickness. Indirect selection can be performed on other traits having a significant association with the trait of interest.

Table 6. Correlation coefficient among traits

| LW   | LL     | SD    | IL     | DTH   | FL    | FW    | FD    | FT    | ST    |
|------|--------|-------|--------|-------|-------|-------|-------|-------|-------|
| LW   | 0.787**|       |        |       |       |       |       |       |       |
| LL   | -0.086 | 0.189 |        |       |       |       |       |       |       |
| SD   |        |       | 0.837**| 0.657**| -0.155|       |       |       |       |
| IL   | -0.116 | -0.077| -0.095 | 0.069 |       |       |       |       |       |
| DTH  | 0.302  | 0.561**| 0.316  | 0.227 | -0.301|       |       |       |       |
| FL   | 0.433* | 0.460*| 0.230  | 0.402*| -0.307| 0.744**|       |       |       |
| FW   | 0.361  | 0.400*| 0.318  | 0.342 | -0.353| 0.593**| 0.927**|       |       |
| FD   | 0.457* | 0.369*| -0.059 | 0.409*| -0.149| 0.376*| 0.791**| 0.812**|       |
| FT   | 0.010  | -0.020| 0.268  | -0.086| 0.182 | -0.096| 0.065 | 0.100 | 0.105 |
| ST   | -0.387 | 0.023 | 0.001  | -0.253| 0.241 | 0.220 | -0.122| -0.050| -0.090| 0.013 |

Notes: LW=Leaf width; LL=Leaf length; SD=Stem diameter; IL=Internode length; DTH=Days to harvest; FL=Fruit length; FW=Fruit weight; FD=Fruit diameter; FT=Flesh thickness; ST=Skin thickness; TSS=Total soluble solids (°Brix)

* Significant at P < 0.05
** Significant at P < 0.01
4. Conclusion
The genotype had significant effects on all observed quantitative characters, namely leaf width, leaf length, stem diameter, internode length, days to harvest, fruit length, fruit weight, and total soluble solids. All observed genotypes have similar vegetative traits, specifically green stem color, dark green leaf color, and bright yellow flower color. The SMM, IPB HD1, and IPB HD4 have good fruit traits as compared with Alisha F1, and therefore are considered potential for developing improved hybrid honeydew varieties.

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