The papaya selection based on fruit characters: a way to assembly new preferred variety

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Abstract. The recent program for assembly new papaya variety was aimed to improve its quality, which based on consumer preference on papaya fruit characters namely size (small to medium), flesh thickness, flesh color (reddish, orange and chewy), and the taste (sweet). To get that kind of papaya variety, a plant breeding program could be applied to assembly. Indonesian Tropical Fruit Research Institute (ITFRI) had conducted several papaya hybridizations in order to obtain a wide genetic variability. The study was carried out in Sumani Experimental Field of ITFRI, Solok Regency, West Sumatra, and performed to select high-quality papaya hybrids based on the fruit characters. The tested genotypes were selected based on its heritability index on fruit size (length, diameter, and weight), flesh thickness and total dissolved solids (TSS). As the results, six papaya varieties were selected based on fruit character, which mirroring best quality of papaya fruit.

1. Introduction

Indonesia is a country that has wide diversity of papaya, particularly on fruit quality characters which is an important resource on variety assembly [1,2]. Papaya variety which has high quality of fruit can be assembly by utilizing the germplasm richness, in order to improve market competitiveness, therefore consumer preference to papaya variety is required to be considered [3]. Consumer preference can be classified according to domestic and foreign market. Domestic market required papaya with medium size, sweet taste, not soft texture, red color and thick fruit flesh, as well as long shelf life [4]. In domestic medium up class societies, they prefer papaya with small size, sweet taste, and no fragrance [4,5]. Preference in foreign market is varied, most consumers in developed countries, such as United States, Australia, Japan, and Netherland choose Solo Sunrise papaya type, which are small in size, soft and red to orange color flesh [6,7].

Technique to assembly superior papaya variety was through the following steps namely germplasm collection, parent selection, hybridization, evaluation, and adaptation testing. Selection, is important step in plant breeding to improve the quality of papaya fruit. To do selection, genetic parameters are commonly used that are heritability, genetic gain, and genetic variation coefficient. Genetic gain is the response of selection; due to selection is based on principles that selected individuals have better performance compared to the average performance in the population. Previously described that quantitative traits, genetic gains are determined by population average alteration [8]. Heritability value suggests the effect of genetic and environment on the population, thus the combination of genetic gains and heritability is more dependable to predict a final result for improved individual traits [9].
2. Materials and methods

This research was conducted on Sumani Experimental Field of Indonesian Tropical Fruit Research Institute (ITFRI) located in Solok Regency, West Sumatera, Indonesia. We use 70 hybrids of papaya population produced from single cross, double cross, three-way cross among parents of ITFRI collection. These papaya variety namely BT-1, BT-2, BT-3, BT-4, BT-K, Dampit, Tangkai Ungu, and Sungai Tarab. The experiment was designed as randomized block design with hybrid variety as treatments and each replicated three times. The observed fruit characters qualities were fruit stalk length (FSL), fruit length (FL), fruit weight (FW), fruit circumference (FC), fruit diameter (FD), flesh thickness (FT), fruit hardness (FH), peel hardness (PH), and total soluble solid (TSS).

The data diversity resource was analyzed, then followed with selection steps. The selection was conducted based on nine observed fruit quality characters, then six best variety among them were chosen. Genotypes with FSL, FT, FH, PH, TSS values above population average were assigned with plus (+) signs, whereas FL, FW, FC, FD values below the population average were assigned with plus (+) signs. Genotypes with the most + signs were selected.

Heritability and genetic gains values were also calculated in this study. Heritability prediction was conducted based on average basis, which is mean that all components were used to measure corrected phenotype variation using replication (r) and location (l). Heritability was calculated using formula below:

\[ H_{bs} = \frac{\sigma^2_G}{\sigma^2_p} \]

Which was

\[ \sigma^2_G = \frac{KTG - KTG}{rl} \]
\[ \sigma^2_p = \frac{KTE}{\sigma^2 + \sigma^2_G} \]

Genetic gain predicted using half-sib Progeny test [10] based on formula below:

Selection differentiation:

\[ S = X_s - X_0 \]

\( S \) was average selected genotypes, and \( X_0 \) was overall average.

Annual genetic gain was calculated:

\[ \Delta G = (c/y) H_{bs} \cdot S \]

\( c \) was parent control and \( y \) were number of years per cycles.

Annual genetic gain percentage \( \Delta G (\%) \) was calculated:

\[ \Delta G (\%) = \Delta G/X_0 \times 100\% \]

All data were analyzed using SAS 9.0 software.

3. Results and discussions

Variation analysis on fruit quality characters of 70 papaya genotypes showed significant difference for all observed parameters that are FSL, FL, FW, FC, FD, FT, FH, PH, and TSS. Based on heritability values, selection of high heritability can be conducted on early generation, and vice versa. Characters with high heritability are easier to pass down to the next generation because it is mostly affected by genetic factors rather than environment. In this study, fruit characters which have high heritability values are fruit weight, fruit length, fruit circumference, flesh thickness, and TSS, thus further selection should conduct based on those traits (Table 1).

Selection of 70 papaya genotypes based on nine characters combination was conducted concurrently. The similar selection method had conducted by Ramos et al [11] on papaya backcross population based on four main characters, which were production, TSS, peel hardness, and flesh hardness. Previous study had also Budiyanti and Hardiati [12] using the same method on Salacca plant population. Table 2 showed maximum, minimum, and average values of several fruit quality characters of 70 tested papaya genotypes. Fruit size can be determined by fruit length, circumference, diameter, and weight. In the current research, it was targeted so select small to medium size papaya
according to the preference of domestic and foreign markets. Fruit size and shape, smooth no stain peel, and interesting flesh and peel color are the main characters which are determined papaya market price and export value [13,14].

Table 1. The value of heritability, average, selected genotypes average, selection differentiation, genetic gain per cycles, and percentage genetic gain per cycles of 70 papaya hybrids accessions.

| Characters genotype | FSL (cm) | FW (kg) | FL (cm) | FC (cm) | FD (cm) | PH (kg/cm²) | FT (kg/cm²) | PT (kg/cm²) | TSS (%) |
|---------------------|---------|--------|---------|--------|--------|-------------|-------------|-------------|--------|
| Heritability (%)    | 0.48    | 0.86   | 0.84    | 0.70   | 0.37   | 0.47        | 0.80        | 0.54        | 0.77   |
| Average             | 3.59    | 936.10 | 22.16   | 28.37  | 9.28   | 0.79        | 2.65        | 0.27        | 11.93  |
| Selected genotypes  |         |        |         |        |        |             |             |             |        |
| average             | 3.78    | 727.20 | 20.54   | 27.36  | 8.70   | 0.83        | 2.62        | 0.27        | 12.16  |
| Selection            |         |        |         |        |        |             |             |             |        |
| differentiation      | 0.19    | 208.90 | -1.62   | -1.01  | -0.58  | 0.04        | -0.03       | 0.00        | 0.23   |
| Gain per cycles      | 0.09    | 179.12 | -1.36   | -0.71  | -0.21  | 0.02        | -0.02       | 0.00        | 0.17   |
| % Gain per cycles    | 2.50    | -19.13 | -6.15   | -2.49  | -2.30  | 2.11        | -0.87       | 0.69        | 1.46   |

FSL: fruit stalk length, FL: fruit length, FW: fruit weight, FC: fruit circumference, FD: fruit diameter, FR: flesh thickness, FH: fruit hardness, PH: peel hardness, and total soluble solid (TSS)

The papaya weight below 1000 gram is classified as medium size, for example Callina which is popular in the market [4]. The foreign markets choose small size papaya, such as Solo Sunrise with 300 – 500-gram fruit weight [15]. The average fruit weight of 70 tested genotypes was 936 g, thus genotypes with lower fruit weight below the average were chosen. The selection was also conducted on genotype with fruit length, circumference, and diameter which are smaller than population average values. Previous study Nishimwe G [16], suggested that papaya categorized as small size when the fruit weight is below 500 g, length less than 15 cm, and diameter not more than 10 cm. Furthermore, medium size fruits were 500 – 1000 g weight, 10 -13 cm fruit diameter, and 15 - 25 cm length, whereas big size were range at 1000 – 3000 g, length above 25 cm, and diameter more than 13 cm.

Peel and flesh hardness of papaya fruit is correlated with fruit shell life and consumers preference of fruit texture. Most of consumers preferred papaya with chewy texture, the higher fruit and peel hardness, the longer fruit shelf life, thus liked more. Papaya flesh is easy to become soft and yellowed, as well as short shelf life due to its climatic behavior [17,18].

Table 2. Average, maximum, and minimum values of fruit quality characters of 70 papaya genotypes.

| Characters              | Average | Minimum | Maximum  | KT (%)  | CV (%) |
|-------------------------|---------|---------|----------|---------|--------|
| Fruit stalk (cm)        | 3.59    | 2.1     | 9.00     | 1.88**  | 20.37  |
| Fruit weight (g)        | 936.10  | 475.71  | 29.75    | 340771.44** | 23.54  |
| Fruit length (cm)       | 22.15   | 16.20   | 43.50    | 32.03** | 10.14  |
| Fruit circumference     | 28.37   | 20.16   | 44.50    | 61.44** | 15.09  |
| Fruit diameter (cm)     | 9.28    | 5.00    | 14.20    | 6.85**  | 22.44  |
| Peel hardness (kg/cm²)  | 0.79    | 0.55    | 0.97     | 0.007** | 7.89   |
| Flesh hardness (kg/cm²) | 0.27    | 0.01    | 0.72     | 0.02**  | 33.99  |
| Flesh thickness (cm)    | 2.65    | 1.45    | 3.92     | 0.28**  | 8.99   |
| TTS (briks)             | 11.93   | 8.66    | 14.80    | 2.23**  | 6.08   |

ns: non-significant, **: significant on p <1%, *= significant on p <5%

Based on fruit weight, six selected genotypes were chosen and had range from 600-900 g (Table 2), thus can be classified as medium size fruit [16], nonetheless six selected genotype had diameter of 8-9 cm which can be categorized as small fruits. Fruit flesh thickness was varied from 2.4 to 2.8 cm which are within the range of fruit size on [19, 20] which was 2.3 – 3.5 cm from 12 accessions [21], which
was 2.9 – 3.6 cm from ten hybrids. Research results from previous study Barboza et al., [22] in papaya Brazil center production, demonstrated that papaya sweet taste is varied 8.11 °brix, which is lower than TSS on the recent research (more than 12.1 °brix). The result show that papayas in this research are sweeter than Brazilian and European papaya which ranged from 9.59 to 8.76 (minimum) and 9.14 and 10.00 °brix (maximum) [23].

Table 3. Fruit quality characters of six selected papaya genotypes.

| Characters /Genotypes   | No.27 | No.29 | No.35 | No.42 | No.49 | No.50 |
|-------------------------|-------|-------|-------|-------|-------|-------|
| Fruit stalk (cm)        | 3.43  | 4.04  | 3.64  | 4.11  | 4.14  | 3.36  |
| Fruit weight (g)        | 636   | 684.9 | 663.7 | 922   | 693   | 763.3 |
| Fruit length (cm)       | 20.88 | 20.78 | 20.77 | 20.7  | 20.58 | 19.55 |
| Fruit circumference (cm)| 26.42 | 26.74 | 26.06 | 29.63 | 26.68 | 28.65 |
| Fruit diameter (cm)     | 8.52  | 8.76  | 8.2   | 9.16  | 8.53  | 9.06  |
| Peel hardness (kg/cm2)  | 0.83  | 0.81  | 0.84  | 0.86  | 0.81  | 0.81  |
| Flesh hardness (kg/cm2) | 2.51  | 2.42  | 2.62  | 2.81  | 2.75  | 2.6   |
| Flesh thickness (cm)    | 0.32  | 0.28  | 0.22  | 0.32  | 0.22  | 0.28  |
| TTS (°brix)             | 12.17 | 12.16 | 12.17 | 12.13 | 12.33 | 12.01 |

4. Conclusion

As the conclusion this study, shows that tested papaya genotypes can be selected based on high heritability index on fruit size (length, diameter, and weight), flesh thickness and total dissolved solids. Among 70 papayas genotype, six of them were selected according to its best fruit quality characters, namely genotypes code 27, 29, 35, 43, 49, and 50. The six selected genotypes had sweet taste, medium fruit size and hard of flesh texture.

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