Phenotypic and genotypic correlation among taste attributes and weight of green bean in Arabica coffee (*Coffea arabica* L.)

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Abstract. The coffee taste may primarily affect consumers in choosing coffee to drink. Information on phenotypic and genetic correlation of taste attributes of Arabica coffee is still lacking. The objective of this research was to determine the phenotypic and genotypic correlation among taste attributes and green bean weight of Arabica coffee. In this study, Nested design was used. The taste attributes and green bean weight of 28 genotypes of Arabica coffee growing in North Sumatra Province was analysed. In this research, it is hypothesized that taste attributes and green bean weight have significant phenotypic and genotypic correlation one another. The research result showed that total score performed significant genotypic correlation with fragrance, flavour, aftertaste, acidity, body and overall, respectively. Selection for aftertaste might be the first priority to get higher total score ($r_G = 0.953^{**}$). Sweetness had significant genetic correlation with green bean weight ($r_G = 0.420^*$). Total score of the taste attributes showed the highest phenotypic correlation with acidity ($r_P = 0.862^{**}$). Weight of green bean could not be used as selection parameter for better taste because no taste attribute did show phenotypic correlation with green bean weight. Breeding for taste quality through hybridization could be necessary in future research.

1. Introduction
Phenotype ($P$) is the summation genotypic or genetic effect ($G$) and environment effect ($E$) which is simply expressed in the equation $P = G + E$. The correlation between phenotypes of different traits is defined as the phenotypic correlation ($r_P$). The correlation of genotypic effects free from the environmental effect is expressed by the genotypic correlation ($r_G$). Information about genotypic correlation between two traits is used in deciding whether to select directly for a target trait or indirectly for a secondary trait. Hence, selection for certain trait may affect other traits. Significant genotypic correlation one another were shown by several taste attributes [1][2]. Researches on taste quality of coffee genotypes are still seldom. However, taste of coffee might be improved through breeding such as interspecific hybridization, crossing within species and F1 hybrids [3-10].

In North Sumatra Province of Indonesia, Arabica coffee was cultivated since more than one hundred years ago, and since then has a significant economic [11]. Coffee consumers look for delicious coffee that fit their taste. Hence, it is important to breed superior genotypes of coffee that produce delicious coffee. However, information on phenotypic and genotypic correlation of green bean weight with taste attributes of Arabica coffee plants found in this province was not yet available. Information on these musts be very important for coffee breeding to create coffee that fits the consumer’s needs. Hence, the objectives of this research were to determine phenotypic and genotypic correlation among green bean...
weight and taste attributes. It was hypothesized that phenotypic correlation \( (r_P) \) and genotypic correlation \( (r_G) \) among weight of green bean of and taste attributes and were significantly correlated.

2. Materials and Method

2.1. Data collection
Taste attributes and green bean weight of 28 genotypes of Arabica coffee growing in North Sumatra Province were analysed. The nested design with three factors was used according to [12]. Seven districts were selected. In each district, two sub districts were selected. Two coffee farms (which were then treated as genotypes) in each sub district were chosen. On each farm, 200–400 coffee plants were 6–7 years old of age with shoot of bronze-coloured leaves and bearing red ripe fruits. The harvest frequency was once in two weeks. Four samples were created by dividing each farm into four similar large sub farms. In order to produce the green beans, the harvested ripe fruits were treated by using full washed method according to [13]. The Cupping Protocols of the Specialty Coffee Association of America [14] was used to obtain the taste attributes. The taste test was carried out by the panel of coffee taste testers comprised of Licenced Q Graider and trained experienced coffee tasters.

2.2. Data analysis
The hierarchical cluster analysis measured with squared Euclidean distance was used to analysis character of population. Phenotypic correlation coefficient \( (r_{P(xy)}) \) and genotypic correlation coefficient \( (r_{G(xy)}) \) between two phenotypes \( (x \text{ and } y) \) were calculated as:

\[
\begin{align*}
 r_{p(xy)} &= \frac{\text{cov}_{P(xy)}}{s_{Px} \times s_{Py}}^{0.5} \\
 r_{g(xy)} &= \frac{\text{cov}_{G(xy)}}{s_{Gx} \times s_{Gy}}^{0.5}
\end{align*}
\]

Note:
\( \text{cov}_{P(xy)} = \) phenotypic covariance between phenotypes \( x \text{ and } y \)
\( s_{Px}^2 = \) phenotypic variance of phenotype \( x \)
\( s_{Py}^2 = \) phenotypic variance of phenotype \( y \)
\( \text{cov}_{G(xy)} = \) genotypic covariance between phenotypes \( x \text{ and } y \)
\( s_{Gx}^2 = \) genotypic variance of phenotype \( x \)
\( s_{Gy}^2 = \) genotypic variance of phenotype \( y \) [15].

Phenotypic correlation coefficient \( (r_{P(xy)}) \) and genotypic correlation coefficient \( (r_{G(xy)}) \) were tested for significance at \( \alpha = 0.05 \) and \( \alpha = 0.01 \) at certain degree of freedom (= error degree of freedom subtracting by 2) [12]. Phenotypes that performed significance at F-test were used in the correlation tests. The data were analysed by using Excel 2007 and SPSS Version 19.

3. Results and Discussion

3.1. Character of population
The cluster dendogram revealed that the genotypes could be divided into three main groups (Cluster 1a, Cluster 1b, and Cluster 2) based on the taste attributes and green bean weight (Figure 1). It indicated a significant variation among genotypes. Phenotypic variation could have correlation with genotypic variation of coffee genotypes [16].

3.2. Phenotypic correlation
Fragrance/Aroma significant phenotypic correlated with Flavour, aftertaste, acidity, body and total score (Table 1). Flavour displayed significant phenotypic correlation also with aftertaste, acidity and total score, respectively. Aftertaste showed significant phenotypic correlation with acidity, body and total score as well. The highest phenotypic correlation coefficient was showed by correlation of acidity with total score \( (r_P = 0.862**) \). Regarding phenotypic correlation, this research result was similar to the research result found by [1,3,11] that fragrance/Aroma had significant phenotypic correlation with
Flavour, acidity and body while Flavour displayed significant phenotypic correlation with acidity, and acidity had significant phenotypic correlation with body. Contrary to this research, [11] found significant phenotypic correlation between green bean weight with Flavour while [1] revealed significant phenotypic correlation between green bean weight and body.

3.3. Genotypic correlation
Fragrance/Aroma performed significant genotypic correlation with Flavour, aftertaste, acidity, body, balance, overall and total score, respectively (Table 1). Flavour showed significant genotypic correlation also with aftertaste, acidity, body, balance, overall and total score, respectively. Overall had significant genotypic correlation with total score as well. Genotypic correlation coefficient between aftertaste and total score was the highest score ($r^G = 0.953^{**}$).

This research result concerning genotypic correlation supported [1] who found that fragrance/Aroma performed significant genotypic correlation with acidity and body while Flavour showed significant genotypic correlation with acidity, body and total score. The findings of this research were in line with the research conducted by [1] that green bean weight did not genotypically correlate with fragrance/Aroma, Flavour, acidity, body and total score. Because total score performed significant genotypic correlation with fragrance, Flavour, aftertaste, acidity and bod, respectively (Table 1), then selection for one of these parameters could influence total score. Selection for aftertaste might be the first priority since aftertaste had the highest genotypic correlation with total score ($r^G = 0.953^{**}$) (Table 1).
1). Besides, aftertaste also showed positive genotypic correlation with fragrance, Flavour, acidity and body, respectively.

Table 1. Phenotypic correlation coefficient ($r_P$) and genotypic coefficient correlation ($r_G$) among taste attributes and hundred bean weight

|                     | Flavour | Aftertaste | Acidity | Body | Balance | Sweetness | Overall | Total score | Hundred green bean weight (g) |
|---------------------|---------|------------|---------|------|---------|-----------|---------|-------------|--------------------------------|
| Fragrance           | $r_P$   | 0.786      | 0.459   | 0.494| 0.405   | 0.088     | -0.074  | 0.247       | 0.482                          |
|                     | $r_G$   | 0.981      | 0.830   | 0.987| 0.968   | 0.508     | 0.023   | 0.418       | 0.892                          |
| Flavour             | $r_P$   | 0.619      | 0.436   | 0.358| 0.065   | -0.182    | 0.112   | 0.395       | -0.070                         |
|                     | $r_G$   | 0.767      | 0.883   | 0.791| 0.620   | -0.278    | 0.428   | 0.639       | -0.198                         |
| Aftertaste          | $r_P$   | 0.640      | 0.409   | 0.073| -0.180  | 0.121     | 0.504   | -0.081      |                               |
|                     | $r_G$   | 0.909      | 0.624   | 0.211| -0.376  | 0.780     | 0.953   | -0.260      |                               |
| Acidity             | $r_P$   | 0.736      | 0.137   | 0.021| 0.074   | 0.862     | -0.008  |             |                               |
|                     | $r_G$   | 0.992      | 0.339   | 0.382| 0.428   | 0.943     | -0.089  |             |                               |
| Body                | $r_P$   | 0.077      | 0.069   | 0.097| 0.495   | -0.032    |         |             |                               |
|                     | $r_G$   | 0.344      | 0.267   | 0.387| 0.921   | 0.033     |         |             |                               |
| Balance             | $r_P$   | -0.283     | -0.179  | 0.059| -0.057  |           |         |             |                               |
|                     | $r_G$   | -0.809     | -0.993  | -0.068| -0.211  |           |         |             |                               |
| Sweetness           | $r_P$   | 0.049      | 0.484   | 0.128|         |           |         |             |                               |
|                     | $r_G$   | 0.553      | 0.192   | 0.420|         |           |         |             |                               |
| Overall             | $r_P$   | 0.297      | 0.012   |     |         |           |         |             |                               |
|                     | $r_G$   | 0.639      | -0.133  |     |         |           |         |             |                               |
| Total score         | $r_P$   |             |         |     |         |           |         |             | -0.059                         |
|                     | $r_G$   |             |         |     |         |           |         |             | -0.284                         |

n 28.
r tabular value at $\alpha$ 0.05 = 0.374
$\alpha$ 0.01 = 0.478
* = significant at $\alpha$ 0.05
** = significant at $\alpha$ 0.01
ns = not significant.
The results mentioned above caused consequences for selection method in coffee breeding. For higher taste score, aftertaste should be selected first. Green bean weight might not be a selection parameter for higher taste because it had no significant phenotypic and genotypic correlation with all attributes of taste and total score of taste.

4. Conclusions
Most of the taste attributes showed significant genotypic correlation one another. Aftertaste should be selected first to get higher total score. All taste attributes did not phenotypically correlate with green bean weight. Hence, weight of green could not be used as selection parameter for better taste. In future research, selection based on taste attributes would be necessary in the coffee breeding.

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