Superior varieties of robusta coffee adapted to high elevation based on farmer selection

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Abstract. Indonesia is one of world’s top five coffee producers and exporters. Two species of coffee commonly grown are Arabica (Coffea Arabica L.) and Robusta (C. canephora var Robusta). However, a few farmers at highland (> 900 m above sea level) of South Sumatera and Bengkulu provinces were keep interested to grow Robusta instead of Arabica. Gradually, they develope new superior clones selected from adjacent seed-derived populations using top grafting technique. Surveys was aimed to identify promising farmer’s selected clones to release as new superior varieties adaptive to high elevation. There are four promising clones, namely Pandi, Rakimin, Pawi, and Jasli, could be clearly distinguished morphologically. The average yield ranging from 2.14 to 3.85 ton of marketable green coffee bean per ha, substantially higher compared to check variety of BP 358 (< 1 ton per ha). Cup quality of those promising clones were categorized as fine Robusta as total scores resulted from sensory/cupping test were higher than 80 (ranging from 81.25 to 83.00) with some spicy and nutty notes. Based on those characteristics, it was reasonable to propose those four promising clones to be released as new superior varieties adaptive to high elevation.

Keywords: Fine Robusta, highland coffee, local varieties, participatory clonal selection

1. Introduction

Indonesia is one of the world’s largest Robusta coffee producers. This coffee species has been mainly developed by smallholders in South Sumatera [1], including Kota Pagar Alam. Kota Pagar Alam, which is located in a mountainous area, with characteristics rich in soil, cold weather, and high rainfall, make this city famous for its high quality coffee, namely “Kopi Basemah”. Coffee beans produced on the highlands give rise to special flavors and aromas of brewing so that they are in great demand by local and foreign consumers. This is very reasonable because the resulting aroma can be smelled even before the coffee is brewed.

Selection for the best Robusta coffee clones has been actively carried out by some creative farmers in Kota Pagar Alam area, although the selection criteria are relatively simple, which emphasizes on high yield per tree, large coffee fruit and seed size. At present, there are several promising selected clones and subsequently developed by other coffee farmers, which make these clones spread to several locations in Kota Pagar Alam. These clones are propagated by farmers using cuttings from plagiotropic shoots grafted on old or less productive coffee plants. Plagiotropic shoots will then develop into flowering branches [2], so that at the age of 1.0-1.5 years after grafting, plants begin flowering and produce berries because they originate from branches that physiologically enter
the post-juvenile phase. Therefore, clonal populations of local adapted Robusta coffee resulting from this kind of propagation technique are now commonly found in Kota Pagar Alam areas.

Participatory varietal selection has been very common for several cash crops in developing countries where informal seed exchanges are more important for small holders [3]. Moreover, low input clones with high yield and good adaptability to local environment are preferable for them [4]. The superior clones of Robusta coffee that have been selected by farmers and proven to be adaptive in the highlands have the potential to be used as a source of seeds in supporting government programs to increase the productivity of coffee plants. Unfortunately, according to Indonesian government seeds regulation, farmer seeds are unprotected by law as it could not be certified by seed certification agency. To overcome this problem, Indonesian government has been pushed the local/farmer’s varieties to be released as new superior varieties. So that breeders from any formal institutions should help farmers to prepare any scientific data and document and subsequently submit them to government assessment team. Therefore it is necessary to observe and evaluate the yield and sensory quality of promising Robusta coffee clones selected and developed by farmers in the highland of Kota Pagar Alam.

2. Material and method
These works was conducted for three consecutive years (from 2016 to 2018) in Kota Pagar Alam district, one of the main coffee producers in South Sumatra, Indonesia. The district is located at Dempo mountain slope (03°59'08"–04°15'45"S; 103°07'00"–103°27'26"E) with altitudes ranging from 100 to 3,159 m above sea level (asl) and daily temperatures ranging from 14 °C to 34 °C. Robusta coffee plantations were developed by farmers under shade tree plants, commonly of leguminous family, with less fertilizer and pesticide applications.

Prior to yield observation, there was a preliminary survey to collect some basic information of Robusta coffee clones that selected by farmer in Kota Pagar Alam. Sampling was then arranged based on this information. Robusta coffee-producing areas were mostly on high elevation of more than 700 m asl. However, among 108 Robusta coffee clones selected and developed by farmers using top working method, only four clones were considered as the most promising clones to be proposed as new superior varieties, namely Pandi, Rakimin, Pawi, and Jasli. Those four clones had been massively developed by farmers through coffee-producing areas in the highland of Kota Pagar Alam.

2.1. Identification of pedigree from promising clones
This step is one of a key entry to ensure that each of the four promising clones has distinct genetic makeup as well as not identical to any previously released Robusta coffee varieties. Pedigree of each promising clone was identified through interview sessions with several elders and local farmers who develop those four promising clones. Thus, we can trace back to a single mother tree that used as the source of each developed clone. Hypothetically, these single mother trees were selected individually by farmers from seedling derived Robusta coffee populations.

2.2. Identification of specific morphological markers for each promising clone
The morphological characteristics of each selected clone were determined based on qualitative characters in branches, leaves and fruit, referring to the descriptors from IPGRI [5].

2.3. Yield estimation of promising clones
Samples of 30 plants from each promising clone were randomly selected from farmer’s coffee plantations. The yield of each promising clone (tonnes/ha) was estimated using data on several yield components for 3 consecutive years (2016–2018) with a population density of 1,600 plant/ha, except for Rakimin clones (3,000 plant/ha). Variables observed were number of bearing primaries (α), number of bunch per primary (β), number of fruit per bunch (δ), weight of single normal fruit (ε : derived from weight of 100 normal cherries), percentage of normal cherries (γ), and outturns (λ : ratio
of green bean weight to fresh harvested fruit weight). Estimated potential yield ($\hat{Y}$) was calculated using formula: $\hat{Y} = \alpha \times \beta \times \delta \times \varepsilon \times \gamma \times \lambda \times P \times 10^{-6}$. $P$ is plant population/ha. In the main harvest period, samples of 300 cherries were randomly taken from each promising clone. Those samples were used to calculate the percentage of normal bean, peaberry bean, empty bean, elephant bean, triage bean.

### 2.4. Sensory analysis of promising clones

Final quality of each promising clone was determined by sensory analysis as protocols for Robusta coffee cup quality. The analysis was conducted at Indonesian Coffee and Cocoa Research Institute (ICCRI). Green beans from each promising clone were prepared using a standard dry process until its moisture content was of 11–12%. Samples of 500 g of green coffee beans were taken from each promising clone for sensory analysis which refers to protocols for fine Robusta published by Uganda Coffee Development Authority and Coffee Quality Institute (Hetzel, 2015). Scores for attributes, including fragrance, flavor, taste, salt/acid, bitter/sweet, body, uniform cups, balance, clean cups, and overall were determined. Of which, final scores of ≥ 80 were categorized as Fine Robusta.

### 2.5. Data analysis

Collected data were compiled and the mean value of each quantitative variable was calculated using Microsoft Excel®.

### 3. Results and discussion

#### 3.1. Pedigree of Promising Clones

The history of the development of Robusta coffee in Kota Pagar Alam region began in the Dutch colonial era (in the 1900s), or more than a century ago. Robusta coffee seeds were initially brought and planted by the Dutch in several areas in South Sumatra, including Kota Pagar Alam. Some seeds are also handed over to the community to be planted with intensive crop maintenance and under strict supervision, so that high yields are guaranteed at harvest. Figure 1 shows more details about the history of Robusta coffee development in Kota Pagar Alam.

![Figure 1](image)

**Figure 1.** Historical story of Robusta coffee development in Kota Pagar Alam based on interview study with elders and local farmers

The four promising Robusta coffee clones were generated from each respective single mother tree that previously selected by local farmers. Each single mother tree was the result of individual selection toward open pollinated Robusta coffee populations at 4 distinct locations and held by different local farmers. Each single selected tree was multiplied clonally by using top working method.
Plagiotropic (generative) shoot cuttings were grafted onto less productive plants as rootstocks. Hence, no ortotrophic (vegetative) structure shoot emerge from the growing plant, so that the plant height could be maintained. At present, there are many populations of top grafted Robusta coffee clones spreading across large areas of Kota Pagar Alam. Some of them have been suggested as promising clones to be proposed as new superior varieties of Robusta coffee.

3.2. Specific morphological markers for each promising clones

Morphological variations can be clearly identified among four promising clones. The primary branches of Pandi and Jasli clones showed a spreading habit, whereas Rakimin and Pawi clones had a drooping characteristic (figure not shown). Rakimin clone has more compact plant architecture so it could be grown in denser population (up to 3,000 plants/ha). This agronomic advantage of Rakimin could bring about a higher yield per hectare as shown in Table 1.

![Figure 2](image-url)  
*Figure 2. Different leaf shape and margin of 4 promising Robusta coffee clones: (a) Pandi, (b) Rakimin, (c) Pawi, and (d) Jasli*

Each promising clone could visually distinguished by leaf and fruit characteristics (Figure 2). Pandi clone has thick-broad size and elliptical-curved shape with strong wavy margin of leaf, whereas Rakimin clone has similar characteristics of leaf but smaller and narrower size. Pawi clone has more distinct characteristics of leaf as it has obovate shape and softer leaf blade. On the other hand, Jasli clone has a similar leaf shape compared to Pandi and Rakimin clones but the leaf margins are less wavy and softer leaf blade. Based on mature coffee fruit characteristics, Pandi clone has more distinct morphotype as it has roundish shape with clear strip on the surface of fruit, whereas the rest of three clones have oblongous shape of fruit. However, Rakimin clone has more prominent fruit disc shape with dark green color of pre rippening fruit skin. On the other hand, Pawi clone has yellowish green color with dirty looks surface of fruit, whereas Jasli clone has bluish green color of fruit (Figure 3).

Significant variations of several morphological characters was also observed among Robusta coffee clones developed by farmers in other areas, such as Lampung province [6]. High genetic diversity of Robusta coffee has being associated with self-incompatibility nature of the species [7], so that generates highly heterozygous individuals and populations with high genetic diversity [8]. Despite
of some clear distinctive characteristics among the four promising clones based on morphological markers, a wide genetic variation was also confirmed by molecular marker analysis. The dendrogram of genetic relationships between clones showed that the genetic similarity coefficient of 0.5 produces 3 genetic groups with varying number of members (data not shown). There is one group that contains only a single member (Pandi clone). The high genetic distance between Pandi and the other clones indicates that the clone originates from a distinct genetic base. It is known that there are some exchanges of planting materials among farmers from different regions in South Sumatra province. Therefore, it is possible that the Pandi clone originated from outside the Kota Pagar Alam area.

Figure 3. Distinct fruit shape and color of 4 promising Robusta coffee clones at pre rippening stage: (a) Pandi, (b) Rakimin, (c) Pawi, and (d) Jasli

3.3. Yield variation among the promising clones

Average yields for three years of production (2016–2018) of four promising clones was varied, ranging from 2.14 ton/ha (Pawi clone) to 3.85ton/ha (Rakimin clone). The yields not only vary between the promising clones, but also between years. In 2017 there was generally a sharp decline in yield with an average of 52.49%. The factor of excessive rainfall (Figure 4) is thought to cause most flowers in 2016 flowering season to rot at the time of the anthesis, thus the fruit set is much reduced. However, in the flowering and fruiting season in 2017, the weather conditions are better so that in 2018 the yields return to normal.
Table 1. Average yield of four promising Robusta coffee clones grown at highland of Pagar Alam, South Sumatra for three consecutive years

| Promising Clones | Yield (ton/ha) of production year - |            |            |            | Average |
|------------------|-----------------------------------|------------|------------|------------|---------|
|                  | 2016                               | 2017       | 2018       |            |         |
| Pandi            | 3.50                               | 0.50       | 3.79       | 2.60       |         |
| Rakimin *        | 4.29                               | 3.57       | 3.68       | 3.85       |         |
| Pawi             | 2.67                               | 1.00       | 2.76       | 2.14       |         |
| Jasli            | 2.60                               | 1.30       | 2.86       | 2.25       |         |

Note: * grown at more dense population of 3.000 plant/ha

The smallest yield reduction, which is 16.78%, is shown by Rakimin clone. In contrast, Pandi clone experienced the highest decrease in yield, up to 85.71% (Table 2). This indicates the variation in yield stability between clones. Rakimin clone are thought to be the most stable, while Pandi clone are considered the most unstable in their interactions with changing environmental conditions.

![Figure 4](image-url)  

**Figure 4.** Rainfall pattern of three years interval (2014–2017) at Kota Pagar Alam region

Proportion of normal beans and the value of outturn could reflect the physical quality of coffee beans. The outturn value in general was in the range of 14%–18% [9]. According to Hulupi & Sipayung [10], a coffee variety / genotype has a good physical quality value if the outturn is > 17% and the percentage of normal beans is > 70%. In this study, the result of coffee bean normality test showed that the percentage of normal beans and peaberry beans varied between clones. However, the percentage of normal beans of the four promising clones could be categorized as high because their values were higher than 70%. On the other hand, the percentage of peaberry beans were less than 30%. No empty coffee beans, elephant coffee beans, and triage coffee beans were found in all sample. In addition, it was known that the quality of green coffee beans of four promising clones were categorized as good because the average values of outturn (ratio of green coffee bean to harvested fruit) were > 17% (Table 2).
Table 2. Average yield components of four promising Robusta coffee clones grown at highland of Pagar Alam, South Sumatra

| Promising Clones | Normal beans (%) | Peaberry beans (%) | Outturns (%) |
|------------------|------------------|--------------------|--------------|
| Pandi            | 80.00            | 20.00              | 18.0         |
| Rakimin          | 79.00            | 21.00              | 19.8         |
| Pawi             | 73.33            | 26.67              | 19.8         |
| Jasli            | 75.67            | 24.33              | 18.0         |

3.4. Cup quality of promising clones

Sensory/cupping test results are displayed in the form of sensory attributes (Table 3). The results showed that the four promising clones had final score in the range of 81.75 - 83.50, exceeding the minimum threshold for fine Robusta coffee category, which were 80. Three promising clones, i.e. Pandi, Pawi, and Jasli, had excellent aroma, but only the first has excellent flavor. On the other hand, Pandi, Rakimin, and Pawi clones also showed excellent mouthfeel/body and had chocolaty notes.

Table 3. Average value of sensory test results of four promising Robusta coffee clones grown at highland of Pagar Alam, South Sumatra

| Sensory Attributes       | Promising Clones |
|--------------------------|-------------------|
|                          | Pandi  | Rakimin | Pawi  | Jasli |
| Fragrance/Aroma          | 8.00   | 7.75    | 8.00   | 8.00  |
| Flavor                   | 8.00   | 7.75    | 7.75   | 7.75  |
| Aftertaste               | 7.75   | 7.75    | 7.50   | 7.50  |
| Salt/Acid                | 7.50   | 7.75    | 7.50   | 7.75  |
| Bitter/Sweet             | 7.75   | 7.75    | 7.50   | 7.75  |
| Mouthfeel/Body           | 8.50   | 8.00    | 8.00   | 7.75  |
| Uniform Cup              | 10.00  | 10.00   | 10.00  | 10.00 |
| Balance                  | 7.75   | 7.75    | 7.50   | 7.50  |
| Clean Cups               | 10.00  | 10.00   | 10.00  | 10.00 |
| Overall                  | 7.75   | 7.75    | 7.50   | 7.50  |
| Taint-Faults             | 0.00   | 0.00    | 0.00   | 0.00  |
| Final Score              | 83.00  | 82.25   | 81.25  | 81.50 |

Notes: 6-6.75 = Good; 7 – 7.75 = Very good; 8 – 8.75 = Excellent; 9 – 9.75 = Outstanding.

4. Conclusions
The four promising Robusta coffee clones, namely Pandi, Rakimin, Pawi, and Pandi, have been identified as different clones based on pedigree and morphological data. Moreover, after three years of observation on these four promising clones that selected and planted by farmers in Kota Pagar Alam, South Sumatra, it could be concluded that these four clones have high yield and good cup quality. Therefore, it is appropriate to propose these four promising clones as novel superior varieties, named Basemah 1, Basemah 2, Basemah 3, dan Basemah 4.

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