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Morphological variation among fifteen superior robusta coffee clones in Lampung Province, Indonesia

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Abstract. *Ramadiana S, Hapsoro D, Yusnita Y. 2018. Morphological variation among fifteen superior robusta coffee clones in Lampung Province, Indonesia. Biodiversitas 19: 1475-1481.* This study aimed to characterize morphological variation among fifteen superior robusta coffee clones in Lampung Province. The fifteen clones consisted of four clones released by the Indonesian Coffee and Cocoa Research Institute (ICCRI), i.e. 'BP 409','BP936', 'BP939', 'SA 237', together with eleven superior coffee clones selected by farmers from Tanggamus District ('Tugino', 'Wanto', 'Biyadi', 'Komari', 'Wardi', 'Wariso') and from West Lampung District ('Tugu Kuning', 'Tugu Hijau', 'Tugu Biru', 'Tugu Sari', 'Lengkong'). Fifteen qualitative and seven quantitative morphological characters were evaluated in a randomized complete block design with three replicates for each clone,each replication consisted of two plants. From each plant, four samples were taken from four sides of the plant (north, south, west, and east). It was found that while some morphological characters exhibited negligible variation among clones, there were significant differences between clones for other characters. The characters that did not differ significantly between clones were: shapes of leaf base and leaf tip; petiole color; leaf venation pattern; fruit disk shape; ripe-fruit color; and stipule shape. The characters that varied between clones were shape of leaf lamina (elliptical *vs*. lanceolate); fruit shape (round *vs*. oval); and shape of leaf margins. Morphological variation was also observed in some quantitative characters: canopy diameter; tree height; stem diameter; leaf length; leaf width; petiole length; stipule length; and number of primary branches.

Keywords: Characters, morphology, robusta coffee, superior clones, variability

INTRODUCTION

Robusta coffee is the most widely cultivated coffee species in Indonesia. Province Lampung, on the southern tip of the island of Sumatera, is the largest producer of robusta coffee, with a planting area of 161,693 ha, a total production of 110,318 tons and productivity of 1,004 kg/ha (Directorate General of Estate Crops 2015). The main centers of robusta coffee plantations in Lampung include the districts of West Lampung and Tanggamus. According to Verbist (cited in Community Geographical Indication 2013), Huitema (1935) reported that in 1880 coffee commodities were known in Sukajaya village, Sumber Jaya sub-district of West Lampung.

Robusta coffee crops were developed from introduced plants that have the highest variability in the genus *Coffea* (Cubry et al. 2008; Motta et al. 2014). Robusta coffee is a cross-pollinated species, so the resulting populations tend to be heterozygous for many gene loci. Robusta diversity is thus very large both in terms of morphology, ecological range, and adaptation (Anthony et al. 2007; Missio et al. 2011). The morphological differences are the easiest to see, especially in mature plants.

Development and distribution of coffee plants in farming communities in Lampung are still based on plant materials derived from seeds that are believed to have high production potential. The farmers select superior coffee plants in their gardens and disperse these to other farmers' garden. This pattern of dispersing perceived superior coffee planting material leads to the emergence of new genotypes with diverse phenotypic characters. Currently, the naming of recognized local clones is done by farmers. Therefore, an important task for researchers who aim to raise productivity of coffee plantations in Lampung Province is to carefully characterize the phenotypic diversity of local superior clones and to compare these clones with those of well-adapted clones in the national coffee improvement program.

Phenotypic characterization of robusta coffee clones is an important step towards identification of genetic diversity and its cropping potential for particular environments. Today, methods for discovering genetic diversity include characterization of morphological, biochemical, and molecular markers (Maluf et al. 2005; Achar et al. 2015; Evizal et al. 2015). Of these three types of markers, morphological characters have long been used by plant breeders as possible indicators of genetic diversity and have the advantage that they are simple to assess. Morphological characterization is thus the usual first step in the description and classification of germplasm. However, morphological characterization is relatively ineffective for genetic diversity analysis because the morphological appearance of plants is strongly influenced by environmental factors (Sumirat 2016). Nevertheless, this method is still widely used to estimate species diversity. In addition, morphological characterization and data collection for coffee plants from a particular region are

helpful in studying evolutionary relationships in line with the recorded history of plants in a region.

The study reported in this paper aimed to determine the diversity of morphological characters among fifteen types of superior robusta coffee clones available for use by farmers in Lampung Province, Indonesia.

MATERIALS AND METHODS

This study was conducted from March 2017 to October 2017 in Tanggamus and West Lampung Districts, of Lampung Province, in southern Sumatera. In Tanggamus District, the data were collected from a coffee plantation in Ngarip village, Ulu Belu sub-district at an altitude of 900-1330 meters above sea level, geographically located between longitudes 104° 18`and 105°12` East, and between latitudes 5°05` and 5°56` South. In West Lampung District, the sampled coffee plantations were located in Sumber Jaya and Gedung Surian sub-districts. The geographical location of West Lampung District lies between longitudes 103°35`8" and 104° 33`51" East and between latitudes 4° 47`16 "and 5° 56`42" South, at an altitude of 986 meters above sea level (Figure 1). Exploration was carried out by collecting field data on the types of robusta coffee widely grown by farmers in the study areas. Qualitative and quantitative morphological characters were recorded. Qualitative morphological characters observed for each clone were: leaf base shape; petiole color; stipule color; leaf shape; leaf venation pattern; leaf surface; leaf margin; young leaf color; old leaf color; young fruit color; and ripe fruit color.

Quantitative morphological characters observed for each clone were: canopy diameter; stem diameter; leaf length; leaf width; petiole length; stipule length; number of primary branches; fruit length; fruit thickness; fruit weight; HS (Hard Skin) bean length; HS bean thickness; HS bean weight; Ose bean length; Ose bean thickness; and Ose bean weight. Measurements of qualitative and quantitative variables were performed with three replications. Each replication consisted of two plants. From each plant, four samples were taken from four sides of the plant (north, south, west, and east). Subsequently, quantitative data were analyzed using a complete randomized block design with three replications. Further tests were performed using a 5%-LSD test.

RESULTS AND DISCUSSION

Identification and characterization of local superior robusta coffee clones from Lampung, and of national superior robusta clones

Observations were made on the coffee plants in Edufarm Nestle, a farmer's coffee garden in Ulu Belu sub-district, Tanggamus District and on a coffee farmer's

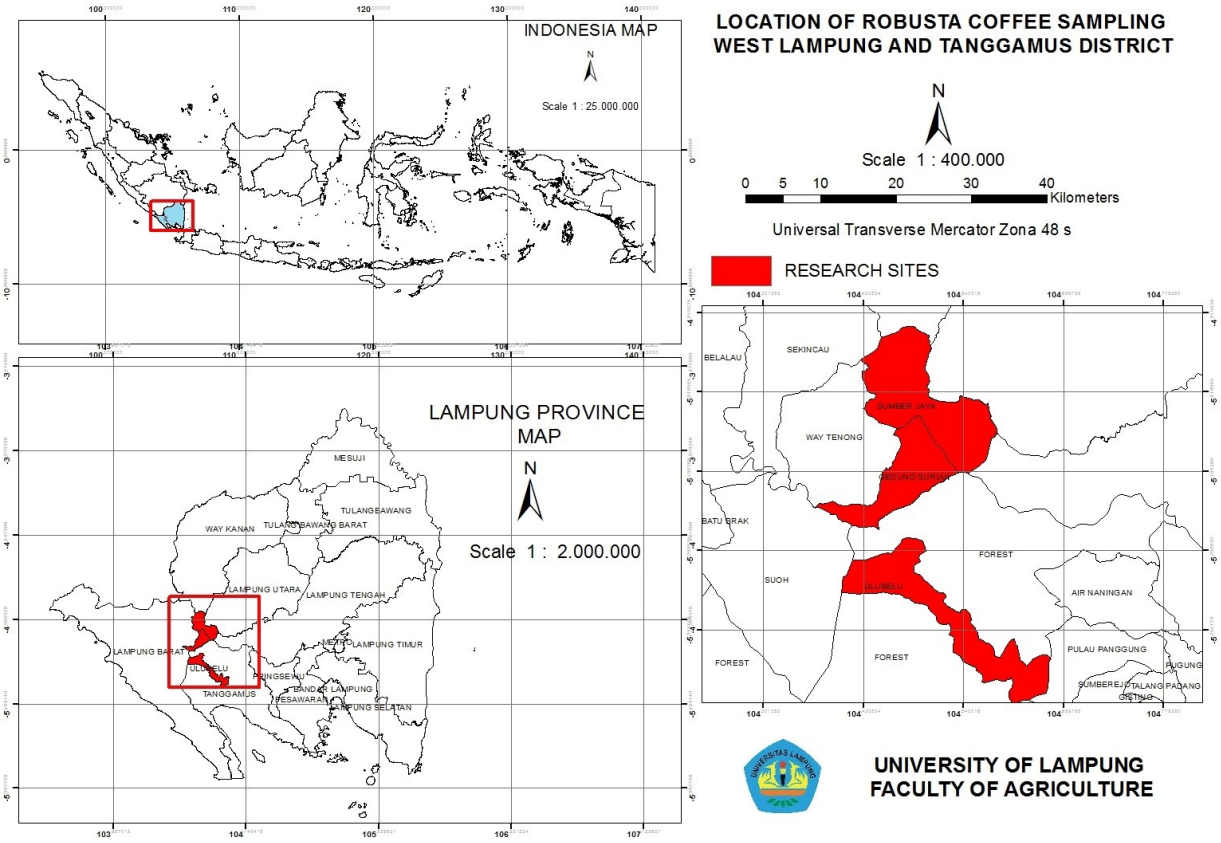

Figure 1. Map of robusta coffee planting area Lampung Province, Indonesia

garden in Sumber Jaya sub-district, West Lampung District. Morphological characteristic were assessed on fifteen robusta coffee genotypes, consisting of 4 national superior clones (SA 237, BP 409, BP 936 and BP 939) and 11 superior local Lampung clones (namely Tugino, Wanto, Biyadi, Komari, Wardi, Wariso, Tugu Kuning, Tugu Hijau, Tugu Sari, Tugu Biru and Lengkong). For some morphological characters, no differences were found between the fifteen genotypes; these non-varying characters were the shape of the base of the leaf; the shape of the tip of the leaf; the pattern of leaf venation; petiole color; form of fruit disk; the color of ripe fruit; and stipule form. For the other qualitative characters (namely leaf shape; leaf surface; leaf margin; young leaf color; old leaf color; fruit shape; young fruit color), differences between genotypes were observed (Table 1 and Figure 2).

Table 2 shows the results of analysis of leaf quantitative characteristics of coffee clones from West Lampung District (Tugu Sari, Tugu Hijau, Tugu Kuning, and Lengkong), Tanggamus District (Tugino, Wanto, and Biyadi), and national clones (SA237, BP 409, BP 939 and BP936). Coffee clones of BP (Besoekisch Proefstation), i.e. BP 936 and BP 939, were among the superior robusta clones recommended for distribution to farmers by the Ministry of Agriculture. SA 273 is another superior clone, recommended for wet climate areas; while BP 409 is a clone recommended as suitable for dry climate areas (Wahyudi et al. 2016).

Table 1. Diversity of qualitative morphological characters among various robusta coffee clones in Lampung Province, Indonesia

Clones	The qualitative morphological characters of robusta coffee clones							
	Leaf shape	**Leaf surface**	**Leaf margin**	**Young leaf color**	**Old leaf color**	**Plant habit**	**Fruit shape**	**Fruit color**
SA 237	Elips	Wavy	Wavy	Green	Green	Shrub	Obovate	Green
BP 409	Elips	Wavy	Wavy	Green	Dark green	Shrub	Roundish	Green
BP 936	Elips	Wavy	Wavy	Green tanned	Green	Shrub	Roundish	Green
BP 939	Elips	Wavy	Wavy	Green tanned	Green	Shrub	Obovate	Stripe green
Tugino	Lanset	Wavy	Wavy	Green tanned	Dark green	Shrub	Roundish	Stripe green
Wanto	Elips	Wavy	Wavy	Green tanned	Dark green	Shrub	Roundish	Stripe green
Biyadi	Elips	Wavy	Wavy	Green	Shiny dark green	Shrub	Roundish	Green
Komari	Elips	Wavy	Wavy	Light green	Dark green	Shrub	Roundish	Green
Wardi	Elips	Wavy rigid	Wavy	Green	Green	Shrub	Roundish	Green
Wariso	Elips	Wavy	Wavy	Green	Green	Shrub	Obovate	Yellowish stripe green
Tugu Hijau	Elips	Not Wavy	Not wavy	Green tanned	Green	Shrub	Roundish	Stripe green
Tugu Kuning	Elips	Not Wavy	Wavy	Yellowish green	Green	Shrub	Roundish	Yellowish stripe green
Tugu Sari	Elips	Wavy	Wavy	Green	Green	Shrub	Roundish	Stripe green
Tugu Biru	Elips	Wavy	Wavy	Green tanned	Green	Shrub	Obovate	Green
Lengkong	Elips	Wavy	Wavy	Green tanned	Green	Shrub	Roundish	Green

Table 2. Diversity of morphological quantitative characters among various robusta coffee clones in Lampung Province, Indonesia

Clones	TD(cm)	CD (cm)	NPB	LL (cm)	LPL (cm)	SL (cm)	LW (cm)
SA 237	18.00 d	258.33 cd	18.33 g	23.33 abc	0.99 e	0.84 a	9.23 de
BP 409	16.00 de	285.00 ab	25.00 def	23.20 bc	1.16 cd	0.60 b	11.48 ab
BP 936	17.00 de	286.67 a	16.00 g	24.11 ab	1.22 bc	0.58 c	10.80 bc
BP 939	14.67 ef	245.00 de	18.67 g	20.61de	1.08 de	0.58 c	9.19 de
Tugino	27.00 c	208.33 fg	24.67 def	20.89 de	0.97 e	0.73 de	9.22 de
Wanto	27.33 c	213.33 fg	23.00 ef	20.89 de	1.17 cd	0.73 de	8.91 e
Biyadi	30.67 b	229.67 ef	25.00 def	19.52 ef	1.17 cd	0.73 de	10.00 cd
Komari	12.33 f	192.50 g	25.67 de	16.86 g	0.69 f	0.69 e	6.44 f
Wardi	17.33 d	217.50 f	22.00 f	21.20 de	1.17 cd	0.73 de	8.63 e
Wariso	12.33 f	228.00 ef	35.00 a	18.17 fg	1.27 bc	0.63 ef	8.43 e
Tugu Hijau	27.00 c	270.00 abc	27.6 cd	23.90 ab	1.46 a	0.68 ef	11.88 a
Tugu Kuning	25.80 c	263.67 bcd	31.20 b	22.31 bcd	1.44 a	0.85 d	9.10 de
Tugu Biru	30.40 b	162.00 h	17.00 g	21.70 cd	1.30 b	0.64 ef	10.72 bc
Tugu Sari	30.63 b	241.00 de	29.43 bc	25.20 a	1.45 a	0.54 f	10.50 c
Lengkong	39.00 a	218.00 f	8.00 h	21.18 de	1.05 de	0.86 d	12.35 a
CV (%)	6.74	5.78	7.77	5.29	6.01	3.83	5.54
LSD 5%	2.60	22.69	3.00	1.91	0.12	0.14	0.91

Notes: TD= trunk (main stem) diameter; CD= canopy diameter; NPB= number of primary branches; LL= leaf length; LPL= leaf petiole length; SL= stipule length ; LW= leaf width. Values within the same column followed by the same letter do not differ significantly at the 5% level of significance

Figure 2. Leaf diversity among robusta coffee clones in Lampung Province, Indonesia

Overall, there were significant differences in terms of leaf characters between the coffee clones. The length of leaf ranged from 25.20 cm to 16.86 cm among the clones. Tugu Sari had the highest value (25.20 cm) for leaf length but the value was not significantly different from that of BP936 (24.11 cm), Tugu Hijau (23.90 cm) and SA 237 (23.33 cm). In contrast, Komari and Wariso had the shortest leaf length with 16.86 cm and 18.17 cm, respectively. Based on the data in Table 2, it can be seen that the leaf length of coffee clones from West Lampung District, namely Tugu Sari, Tugu Hijau and Tugu Kuning, were comparable to that of the Jember clones (SA 237, BP 936 and BP 409). The similar leaf morphological characteristic, i.e. leaf length of Tugu Sari with that of Jember clones, could be attributable to the origin of Tugu Sari itself. According to Evizal et al. (2015), historically, Tugu Sari might have originally come from Jember. This fact might have contributed to the similarities in terms of leaf morphological length between Tugu Sari and the Jember clones. Furthermore, after having been cultivated in West Lampung, the Tugu Sari clone was then introduced to Tanggamus District (Evizal et al. 2015). According to Ruspendi, an agricultural officer in Sumber Jaya Sub-district (Ruspendi, Pers. Comm. 2017), the introduction of

new clones might have led to the creation of clones with new names and characteristics. Based on this information, it might have been expected that Tugu Sari would have some similar characteristics with those of clones from Tanggamus District such as Tugino, Wanto, and Biyadi. However, in this study, it was found that Tugu Sari had a longer leaf length than that of clones from Tanggamus District. This discrepancy might be explained by the possibility that introgression of Tugu Sari characteristics into the coffee lines in Tanggamus has not been completed.

Table 2 also shows that coffee clones from Tanggamus (namely Tugino, Wanto, and Biyadi) had similar leaf length to that of one of the coffee clones from West Lampung (i.e., Lengkong). Again, this similarity could be attributed to the origin of these clones. Lengkong was originally from Tanggamus District and was introduced from there to West Lampung (Evizal et al. 2015). This fact might have contributed to the similarity in leaf characteristic between Lengkong and Tugino, Wanto and Biyadi (Table 2). Compared to that of the Jember clones, these clones shared similarity in term of leaf length with BP 939. In contrast, the coffee clones from Tanggamus (i.e. Komari and Wariso) had shorter leaves than that of the Jember clones (SA237, BP409, BP939, and BP936), West Lampung clones, and even other Tanggamus clones such as Tugino, Wanto, and Biyadi.

In term of leaf width, Lengkong (12.35 cm), Tugu Hijau (11.88 cm) and BP 409 (11.48 cm) had the broadest leaves amongst the clone analyzed. It also can be seen that Lengkong and Tugu Hijau were comparable with the BP 409 clone in leaf width, but were broader than the leaves of the other Jember clones (SA 237, BP 936 and BP 936). The leaves of these two West Lampung clones were also broader than that of Tanggamus clones and the rest of West Lampung clones (Tugu Kuning, Tugu Biru, and Tugu Sari).

Overall, it appeared that coffee clones from West Lampung generally had longer and broader leaves than those of the coffee clones from Tanggamus District (Table 2). This difference could perhaps be attributed to the difference in altitude between West Lampung and Tanggamus. West Lampung District has an altitude of approximately 838.7 m, while Tanggamus District's altitude is around 787 m (Evizal et al. 2015). These results from the current study were in line with results from a previous study in which an increase in the altitude of the growing environment for robusta coffee from 687m to 1100m was associated with an increase in the leaf length (Pauline 2013). The results from the study by Pauline (2013) showed that there was a positive correlation between leaf length and width with the number of coffee fruits formed on the coffee tree. The big leaves may provide an ampler photosynthetic surface that nourishes the vegetative parts and fruits of the trees (Pauline 2013). Thus, it could be expected that those coffee clones from West Lampung and Tanggamus that had comparable leaf characteristics (i.e. in length and width of leaf) to those of the superior national clones, might have similar enhanced coffee fruit production capacity to that of the National coffee clones.

A significant difference among clones in our study was also observed in terms of the length of petiole. Clones from West Lampung (namely Tugu Hijau, Tugu Sari and Tugu Kuning) had longer petioles compared to the petioles of the clones from Tanggamus and Jember. On the other hand, Komari had the shortest petiole, of only 0.69 cm.

There was a wide variation in stipule length among the clones. SA237 clone had the among the longest stipules (8.34 mm), while Tugu Sari (0.54 mm), Tugu Hijau (0.68 mm), and Tugu Biru (0.64 mm) were among the shortest.

Our study also showed that there was a significant variation in diameter of trunk. Lengkong had the widest diameter at 39 cm, while Komari and Wariso had the narrowest diameter (12.3 cm). It also appeared that all clones from West Lampung had wider diameter of trunk compared to the diameters of the national clones Three clones from Tanggamus (Tugino, Wanto, and Biyadi) also had wider trunk diameter than the national clones. Pauline (2013) reported that the diameter of trunk was correlated with green bean yield and with the growth habit. Genotypes with small trunk diameter were characterized by low green bean yield per tree and by dwarf growth habit. Based on this information, it might thus have been expected that West Lampung clones and some of Tanggamus clones could produce coffee trees with high green bean yield and vigorous growth habit.

In our study, the diameters of canopy ranged from 286.7 cm down to 192.5 cm (Table 2). BP 936 and BP 409 had the widest canopies with 286.7 cm and 285.0 cm, respectively. The canopy diameter of BP 409 measured in the current study was in line with the result reported by Hulupi (2016) who reported it to be 2.7 m in size. However, the canopy diameter of SA 237 in the current study was a little bit lower than previously reported (i.e 3 m) (Hulupi 2016). In general, coffee clones from Tanggamus had narrower canopy diameters compared to those of the Jember clones. Except for Tugu Biru and Lengkong, the canopy diameters of all West Lampung clones fell within the range for those of the Jember clones (Table 2). In contrast, Tugu Biru had the smallest canopy, 162.0 cm in width.

Table 2 shows that the number of primary branches also varied among the clones. Wariso had the most (35 primary branches). This was higher than for all the clones from Jember, West Lampung, and Tanggamus. Some clones, West Lampung namely Tugu Hijau, Tugu Kuning and Tugu Sari, had a significantly higher number of primary branches compared to that of the Jember clones. Tugu Biru had a number of primary branches comparable with all the Jember clones. In contrast, Lengkong had the least number (i.e., 8 primary branches).

The number of primary branches is one of the important characters determining the potential for coffee production because more branches can provide for development of an ample photosynthetic area that in turn nourishes tree vegetative parts and fruits (Udarno and Setiyono 2015; Pauline 2013). A higher number of primary branches may indicate a higher production potential. Therefore, it was expected that most of the coffee clones from West

Lampung and Tanggamus districts could have productivity similar or even higher than that of Jember clones. In addition, clones of these clones could be used in selection programs to produce new superior varieties with high number of primary branches.

The wide morphological variation in the vegetative characteristics of the robusta coffee clones summarised above in Table 2 was in accordance with the findings of Cubry et al. (2008) who reported that the robusta species, *Coffee canephora,* displays the highest variability within the *Coffea* genus. This variability also extends to the reproductive characteristics. Table 3 shows the results of our analysis of the green bean characteristics from ten of the superior robusta coffee clones collected from Tanggamus District and West Lampung District. In general, there were significant differences between the clones in the morphological characters of the beans (Figure 3).

Table 3. Diversity of morphological quantitative characters of coffee beans among ten local robusta coffee clones in Lampung Province, Indonesia

Clones	Fruit length (mm)	Fruit thickness (mm)	Fruit weight (g)	HS bean length (mm)	HS bean thickness (mm)	HS bean weight (g)	Ose bean length (mm)	Ose bean thickness (mm)	Ose bean weight (g)
Tugino	19.05 b	13.97 b	2.48 a	16.19 b	6.89 a	0.67 b	14.48 a	5.55 ab	0.53 a
Komari	18.12 c	14.91 a	2.66 a	14.58 c	6.70 ab	0.62 b	12.44 bc	5.56 ab	0.46 b
Biyadi	20.10 a	14.95 a	2.43 b	13.08 de	6.25 cd	0.47 d	11.03 de	5.06 cd	0.35 de
Wariso	16.08 fg	12.97 cd	1.96 c	15.92 b	5.90 d	0.54 c	12.90 b	4.73 de	0.38 cd
Wanto	15.79 fg	12.22 c	2.03 c	14.02 cd	6.43 bc	0.52 cd	11.96 cd	5.34 bc	0.40 c
Tugu Kuning	16.38 ef	12.30 cde	1.62 d	14.18 cd	6.51 abc	0.40 e	11.40 de	4.99 cd	0.33 ef
Tugu Sari	17.06 de	12.80 cde	1.99 c	13.59 de	6.81 ab	0.36 ef	11.15 e	5.18 c	0.30 f
Lengkong	15.59 g	11.73 f	1.37 e	12.27 f	5.31 e	0.31 f	9.42 f	4.40 e	0.19 g
Tugu Biru	17.72 cd	12.24 ef	2.06 c	17.29 a	6.85 a	0.74 a	14.64 a	5.65 ab	0.48 b
Tugu Hijau	16.98 e	12.68 cde	1.73 d	14.51 c	6.75 ab	0.56 c	12.91 b	5.84 a	0.45 b
CV	2.38	3.10	5.02	3.14	3.56	6.23	3.15	3.93	5.78
LSD 5%	0.70	0.70	0.17	0.78	0.39	0.05	0.04	0.35	0.04

Note: Values within the same column followed by the same letter do not differ significantly at the 5% level of significance

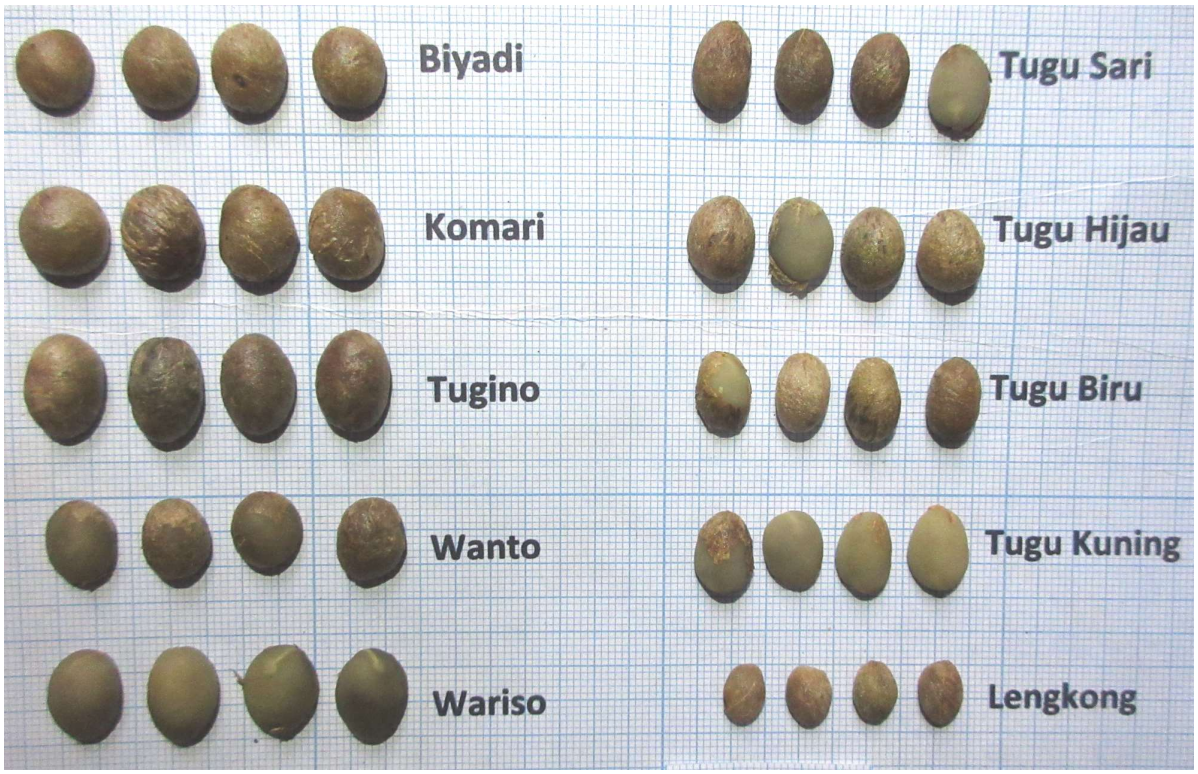

Figure 3. Green bean diversity among clones of local robusta coffee in Lampung Province, Indonesia

In general, coffee clones from Tanggamus produced green beans which were longer, thicker and heavier compared to the clones from West Lampung District. The length of green beans ranged from 20.1 mm to 15.6 mm. Biyadi had the longest beans (20.1 mm), followed by Tugino (19.1 mm) and Komari (18.1 mm). Lengkong, Wanto, and Wariso had the shortest beans (15.6, 15.8 and 16.1 mm, respectively). Tugu Sari, Tugu Biru, and Tugu Hijau were similar to one another in their green bean characteristics. In term of the bean thickness, Biyadi and Komari had the thickest beans (14.91 and 14.95 mm, respectively), while Lengkong (11.7 mm) and Tugu Biru (12.2 mm) had the thinnest green beans. Overall, the green bean weight ranged from 2.66 g to 1.37 g per bean (Table 3; Figure 3). Green beans of Komari and Tugino clones were the heaviest, 2.66 g and 2.46 g, respectively. In contrast, Lengkong (1.37 g) had the lightest green beans.

In conclusions, similarities in quantitative morphological characters were found between certain clones among fifteen robusta coffee clones evaluated in Lampung. Tugu Sari was found to have similar leaf length with that of clones from Tanggamus District such as Tugino, Wanto, and Biyadi. Three clones from Tanggamus (Tugino, Wanto and Biyadi) had wider trunk diameter than the national robusta clones. In terms of green bean characteristics, coffee clones from Tanggamus, in general, produced longer, thicker and heavier green beans than those from West Lampung District. Findings from a previous study by Pauline (2013) have indicated that selection for higher bean yield per tree can be achieved through selection for higher percentage of primary branches, bean weight, canopy diameter, tree height, trunk diameter, bean thickness, bean length, fruit length, inter-node length on orthotropic branches and petiole length. Our study indicates that genetically influenced variation exists amongst Lampung robusta clones for most of these characteristics and suggests that determination of an appropriate selection index based on the most heritable of these characteristics which are correlated with high yield could be a useful approach to generating improved productivity of robusta coffee in Lampung Province.

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