Pelita Perkebunan 38(2) 2022, 98–107
DOI: 10.22302/iccri.jur.pelitaperkebunan.v38i2.323

ISSN: 0215-0212 / e-ISSN: 2406-9574

# Adaptation of Introduced Robusta Coffee Clones in Some Agroclimate Types in East Java

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Received: 3 January 2019 / Accepted: 13 December 2021
[@]The first author passed away after revising this paper manuscript based on reviewers' comments

**Abstract**

Indonesia is the fourth largest coffee producer in the world, although this country is not the origin of coffee plant. Efforts to increase coffee genetic diversity in Indonesia through plant introduction are carried out in order to improve quality and quantity of Indonesian coffee in the international market. The aim of this study was to obtain Robusta coffee clones that are able to adapt in several agroclimate types in Indonesia, high and stable in yield, and eventually they can be cultivated extensively. There were six introduced clones (FRT 04, FRT 06, FRT 07, FRT 09, FRT 23, FRT 65) used in this study. The clones were brought from France and planted on six coffee plantations i.e Bangelan, Kalibendo, Kaliselogiri, Gunung Gumitir, Malangsari, and Silosanen. All of the coffee plantations are located in East Java, Indonesia, with varied in agroclimate types. Data collected concerning plant growth and yield were analysed using the method of additive main effect multiplicated interaction (AMMI) biplot. Results of this study showed that FRT 07 was the most productive clone compared to other Robusta coffee clones tested. Besides, high yield in average of all locations was proved by FRT 07 and FRT 09 clones, particularly number of productive branches per tree, number of bunches per branch, number of fruits per bunch, total number of fruits per tree, and estimated yield of trees. Meanwhile, the highest parameter of weight of 100 fruits was found on FRT 23 clone. In general this study revealed that Bangelan plantation was the location produced high plant growth and yield parameters. Results of multivariate biplot analysis of adaptability of a genotype to an environment demonstrated that FRT 65 clone had a stable yield component in every location. FRT 07 and FRT 09 are clones with site-specific types and resulting better production than FRT 65 in all tested locations. Malangsari was more suitable for FRT 07 or it was more site specific for its adaptation based on the components of Robusta coffee yield traits. FRT 04, FRT 23, and FRT 06 clones showed neither the best fruit yield nor specific adaptations in each area tested, even though they still produce in each period. FRT 09 clone was able to adapt in all tested locations.

**Keywords**: adaptability, clones, agroclimate, locations, AMMI, Robusta coffee, FRT

## INTRODUCTION

More than 70 countries produce coffee, but the majority of global output comes from just the top five producers: Brazil, Vietnam, Colombia, Indonesia, and Ethiopia. Exports of Arabica totaled 80.47 million bags whereas Robusta exports amounted to 49.54 million bags. In 2021, it was estimated that Indonesia produced approximately 774.6 thousand metric tons of coffee. Indonesia is one of the world's leading producers of coffee, and one of its leading exporters (ICO, 2021).

There are about 120 different types of coffee plants that can be distinguished botani- cally. However, the most popular types of coffee plants that also produce the majority of all coffee beans are Arabica and Robusta (Wintgens, 2004). Indonesia's coffee plan- tations cover total area of approximately 1.24 million hectares, 933 hectares of Robusta plantations and 307 hectares of Arabica plan- tations. More than 90 percent of total plan- tations are cultivated by small-scale growers (Ditjenbun, 2021).

Robusta coffee (*Coffea canephora* Pierre ex. A. Froehner) first came to Indonesia in
1900 from Belgian Congo (now Zaire), planted in Malang (Mawardi & Hulupi, 2003). Robusta coffee which was first developed in Indonesia in 1911-1930 was the result of breeding activities in the Dutch government experi- mental station in Bangelan, Malang, East Java (Puslitkoka, 2016). At present, Robusta coffee is mostly cultivated on the island of Sumatra (70.22%), which more than half of Robusta coffee production was significantly produced in three provinces, namely South Sumatra (34.8%), Lampung (20.1%) and Bengkulu (10.2%)

in Brazil is named Conilon variety. Meanwhile
Behailu (2008) classify Robusta coffee into two groups based on the origin of the develop- ment area, namely Congo group which is Robusta coffee from Central Africa and Cameroon and Guinean group is the name of Robusta coffee originating from Ivory Coast (Sumirat *et al.,* 2007).

Coffee quality is determined by geno- type and environmental factors which related to biochemical components in coffee beans that have accumulated during growth period (Cheng, 2016). Globally, Robusta coffee is generally mostly derived from ex-situ collec- tions in several countries with a collection of 700 original genotypes which are based on the area of distribution, characterization and evaluation. Tshilenge *et al.* (2009) state that not only breeding programs can improve the agronomic traits of genotypes, but also plant yield characteristics and genotype and environmental interactions. Nearly a decade Robusta coffee of FRT series have been introduced to Indonesian Coffee and Cocoa Research Institute (ICCRI) from France. However, only a limited information was obtained related with their adaptation to agroclimate conditions of Indonesian in general and especially in East Java. Therefore, there was a need to study the genotype response to the environment with soil type, altitude topography, latitude, and climate to

## MATERIALS AND METHODS

The plant materials used in this study were introduced clones from France i.e. the FRT series consisting of FRT 04, FRT 06, FRT 07, FRT 09, FRT 23, and FRT 65 which had been planted in 2009, located in six

Table 1. Agro-climatic conditions of the six coffee plantations used as experimental sites in this study

| Parameters | Bangelan | G. Gumitir | Kalibendo | Kaliselogiri | Malangsari | Silosanen |
|---|---|---|---|---|---|---|
| Altitude (m asl) | 450-550 | 400-650 | 500-825 | 300-600 | 550-720 | 400-680 |
| Rainfall (mm $year^{-1}$) | 2242 | 2194 | 2175 | 2096 | 2125 | 1903 |
| Climate type * | C Rather wet | B Wet | C Rather wet | D Average | C Rather wet | C Rather wet |
| Main soil types | Latosol | Latosol | Regosol, Andosol and Latosol | Latosol, Regosol | Andosol, Latosol | Latosol, Regosol |

*According to Schmidt & Ferguson (1951) classification.

plantations in East Java, in collaboration with Indonesian Coffee and Cocoa Research Institute. Those coffee plantations belong to PTPN XII that in Indonesian Government Plantation enterprises. The experimental sites were located in six different environmental locations of coffee plantations, namely Gunung Gumitir, Silosanen, Malangsari, Kaliselogiri, Kalibendo, and Bangelan as presented in Table 1.

The research method was adaptability analysis of diversity of interactions between locations, clones and year using biplot addi- tive main effects and multiplicative interaction (biplot-AMMI) analysis. The treatments consisted of six introduces FRT clones which were planted in the six different environ- ments. Observations were carried out during four consecutive years (2014-2017) with three replications for each treatment. Random sampling of five trees per replication for each treatment was cariied out in every

## RESULTS AND DISCUSSION

Yield parameters of six FRT clones of Robusta coffee tested in six coffee planta- tions in East Jawa during four consecutive crop production year periods are presented in Table 2. Significant differences were detected among FRT clones, locations and year. Location-by-year combinations considered separate environments because of drastic differences in climate among years. Coffee plantation environment was a signifi- cant source of variation for yield traits. Clone- by-location and year-by-location interactions were significant for all measured yield traits. These results agree with Asad *et al*. (2009) and Cheng *et al*. (2016) who found signifi- cant genotype environment interactions for paddy yield and coffee quality, respectively.

There was significant effect of among clones on yield traits. FRT 07 and FRT 09 has the highest yield in term of number of productive branches per tree, further FRT 07 also has highest number of bunches per branch, total number of fruits per tree, and estimated yield per tree. Weight of 100 fruits and number of fruits per bunch was found the highest on FRT 23. The lowest yield was found on FRT 06 for all yield parameters observed.

Results of this study show a significant effect of location which can be seen in Table 2 which reveal that Bangelan coffee plantation has the highest yield traits in terms of nearly all parameters observed, except weight of 100 beans and estimated yield per tree. The highest weight of the 100 fruits was found in Kaliselogiri, whereas for estimated yield per tree was observed in Gunung Gumitir.

clones in all environments can be released into broad-adapted clones. Adaptability of plants can trigger the emergence of new genotypes that have very diverse phenotypic characters. This difference can be beneficial because the results obtained also vary and can adapt well to the conditions of the local agroecosystem. Genotype and environmental interactions are different in phenotype values compared to expected genotype and environ- mental interaction values (Kang, 2002).

Table 2 presents annual observation from 2014 to 2017 which was significant differences on all parameters tested. Highest annual result was obtained in 2016 particu- larly for parameters of number of productive branches, number of bunches per branch, number of fruits per bunch, total number of fruits per tree, estimated yield, estima- tion of yield per ha. The highest weight of branches, number of bunches per branch, total fruits per trees estimated yield per hectare, wereas the weight of 100 beans. Estimated yield per tree was the lowest in 2017. This variation may be due to climatic differences in each year in every location tested against for the clones Robusta coffee FRT clones introduced in locations with East Java conditions.

According to Erdiansyah *et al.* (2014), rainfall gives a significant effects on develop- ment of Robusta coffee flowers. The rain that falls when the flowers are blooming and still continues until afternoon, even in form of drizzle, has a huge influence on fruit development. This indicates that the risk of failure of Robusta coffee production in wet areas is quite high, considering the possi- bility of rain disruption at the time of flower expansion which affect fruit development, although

Table 2. Yield trait parameters of six FRT clones of Robusta coffee tested in six experimental sites during four consecutive crop production periods

| Attribute | Observation parameters | | | | | |
|---|---|---|---|---|---|---|
| | Y1 | Y2 | Y3 | Y4 | Y5 | Y6 |
| Locations | | | | | | |
| Bangelan | 38.45 a | 6.09 a | 12.62 a | 3277 a | 135.45 ab | 7691 ab |
| Silosanen | 25.19 ab | 4.15 cb | 8.55 c | 1835 b | 126.32 ab | 3657 cb |
| Malangsari | 17.48 b | 3.77 c | 9.13 bc | 1615 b | 82.51 c | 2979 c |
| G. Gumitir | 34.17 a | 5.43 ab | 12.30 ab | 2430 b | 122.82 b | 8803 a |
| Kaliselogiri | 28.19 ab | 5.25 ab | 11.19 bc | 2126 ab | 140.67 a | 4924 bc |
| Kalibendo | 33.42 a | 3.67 c | 8.20 c | 2989 ab | 132.37 ab | 6720 b |
| Clones | | | | | | |
| FRT 04 | 14.71 bc | 3.61 b | 6.91 c | 872 c | 120.72 ab | 1783 b |
| FRT 06 | 7.64 c | 2.72 b | 6.28 c | 630 c | 117.00 ab | 1585 b |
| FRT 07 | 53.04 a | 6.18 a | 11.35 ab | 4500 a | 131.75 a | 12236 a |
| FRT 09 | 54.90 a | 5.92 a | 11.70 ab | 4164 a | 123.98 ab | 10383 a |
| FRT 23 | 18.70 bc | 4.13 b | 14.56 a | 1552 bc | 134.59 a | 3470 b |
| FRT 65 | 27.90 b | 5.82 a | 11.19 b | 2553 b | 106.98 b | 5312 b |
| Year | | | | | | |
| 2014 | 27.31 b | 5.22 a | 11.79 a | 2917 b | 119.60 b | 6738 a |
| 2015 | 19.86 b | 3.62 b | 7.68 b | 1706 c | 143.52 a | 3905 b |
| 2016 | 47.80 a | 5.11 a | 11.78 a | 4185 a | 124.73 b | 8465 a |
| 2017 | 22.95 b | 4.95 a | 10.08 ab | 705 c | 105.61 b | 4072 b |

Notes: Figures in same column and atribut followed by different letter(s) are not significantly different. Observerd parameters: number of productive branches (Y1), number of bunches per branch (Y2), number of fruits per bunch (Y3), total number of fruits trees (Y4), weight of 100 fruits (g) (Y5), estimated yield (Y6).

A genotype that has adaptability with the same production level may be grown in a variety of environments with broad adapt- ability, therefore the genotype has adapted to different growing conditions in each planted environment (Rasyad & Idwar, 2010). Meanwhile, Nur (2000) mentioned that the amount of rainfall and its distribution in one year has important roles in Indonesian coffee production. This is due to the increase in flowers dropping, especially if the rain falls when flower blooming, beside affected by length of the day (photoperiod) in the equator.

Pujiyanto (1998) also suggested that ideal rain condition for coffee plants is the availability of nine wet months and three dry months. Productive coffee plants show a more neutral day (dry-neutral plant) where their flowers are not sensitive to the influence of day length. Based on the results of analysis of variance between locations and clones showed a significant effect. However, the interaction between of Asad *et al.* (2009). When genotype environmental interactions are qualitative (crossover interaction), breeders must choose one genotype for a particular environment and other genotypes for different environ- ments. This condition will cause difficulties in choosing a stable genotype. The analysis is needed to and to sort stable and specific genotypes. Based on the research results of Rodrigues *et al.* (2013), yield stability testing can determine certain genotypes in different environmental condition and adaptation widely or site-specific. Therefore later, superior clones in all environ- ments can be released as clones that are able to adapt widely.

The interaction effects of clone and location on estimated yield of Robusta coffee of six coffee plantations in East Java are presented in Table 3. When considering estimated yield of coffee trees in all locations, Bangelan showed higher yield compared to other coffee plantations tested, particularly with Kalibendo plantation. However, the yield in Bangelan plantations did not show any significant differences compared to Silosanen, Malangsari, G. Gumitir, and Kaliselogiri plan- tations. Among the FRT Robusta coffee clones, the most productive clone was FRT 07, meanwhile the lowest was FRT 06 clone which is not significantly different from FRT 04 and FRT 13. This was due to the interaction effects of clone and location on yield parameters.

Figure 1 shows the results of multivariate biplot analysis of the adaptability of a geno- type or clone tested with the environment. The results indicated

Table 3. Estimation of tree yields (number of fruits per tree) as indicated by interactions between Robusta coffee FRT clones and six coffee plantations in East Java

| Location | Robusta coffee FRT clones | | | | | | Average |
|---|---|---|---|---|---|---|---|
| | FRT 04 | FRT 06 | FRT 07 | FRT 09 | FRT 13 | FRT 65 | |
| Bangelan | 2446 | 2070 | 7760 | 6488 | 3679 | 5387 | 4638 [a] |
| Silosanen | 284 | 345 | 11417 | 6978 | 1736 | 4440 | 4200 [a] |
| Malangsari | 617 | 1645 | 6215 | 5456 | 2028 | 2506 | 3078 [a] |
| G. Gumitir | 787 | 1885 | 4279 | 3849 | 1750 | 1352 | 2317 [a] |
| Kaliselogiri | 1454 | 0 | 12286 | 5282 | 2120 | 4287 | 4238 [a] |
| Kalibendo | 1098 | 0 | 2917 | 3392 | 1699 | 1950 | 1843 [b] |
| Average | 1114 [c] | 991 [c] | 7479 [a] | 5241 [b] | 2169 [c] | 3320 [bc] | |

Notes: Figures followed by different letter(s) are significantly different at p = 95%.

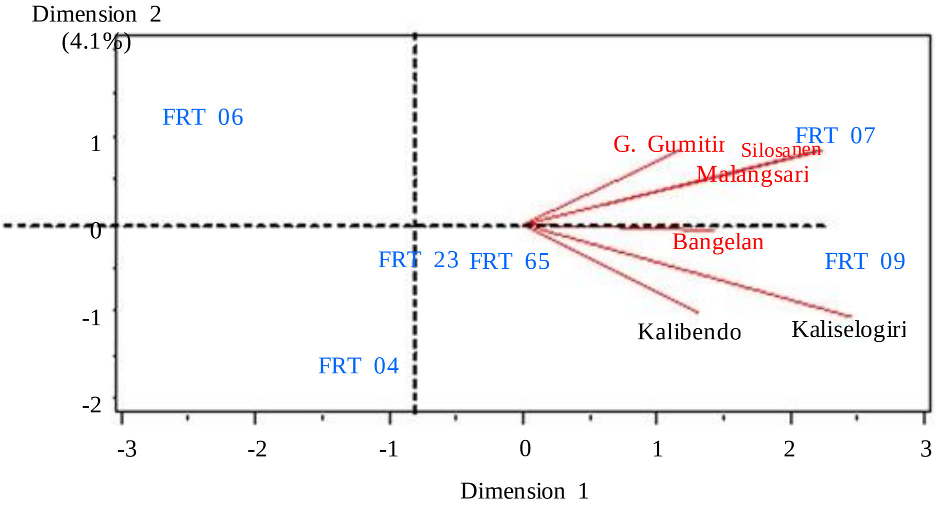


Figure 1. Biplot adaptation of six Robusta coffee clones with six locations of coffee plantations in East Java against plant production components

they are far from zero line and their production is better than FRT 65 in all tested locations. FRT 07 clone in Silosanen and Malangsari plantations has a more suitable or site-specific for the adaptation in term of Robusta coffee production component. Meanwhile, FRT 04, FRT 13 and FRT 06 clones did not show neither best fruit pro- duction nor specific adaptation in each area tested, although they still produce in each period. FRT 09 clone is able to adapt in all tested locations as indicated the distance from the 0 line to the positive right position and location specific for Kaliselogiri.

FRT 04 clone indicates low yield maybe due to unsuitable. This indicates that the clone cannot adapt well to the six locations tested. Meanwhile, FRT 06 has not been able to adapt optimally in all locations, although the coordinate of FRT 06 is in the position of positive-negative adaptation. FRT 13 clone is almost close to the stable line position, but it is still not genetic potential and the interaction between clone with location tested is different in character.

Figure 2 shows the results of multivariate biplot analysis of the clone adaptation during the period of this study based on number of fruits per bunch. It was revealed that Robusta coffee clones, namely FRT 07, FRT 09, and FRT 65 can adapt very well based on number of fruits per tree and number of produc- tive trees throughout the year. Meanwhile, FRT 07 and 09 showed the most stable in fruit production in each year where in 2016 showed very high fruit production. However, based on coffee production, FRT 13 clone did not have extensive adaptation or specific adaptation and gave poor yield every year. Although FRT 04 and FRT 06 clones did not produce fruits every year, they still had a positive effect on the estimated yield during the four coffee harvest periods. FRT 13 and FRT 06 did not show

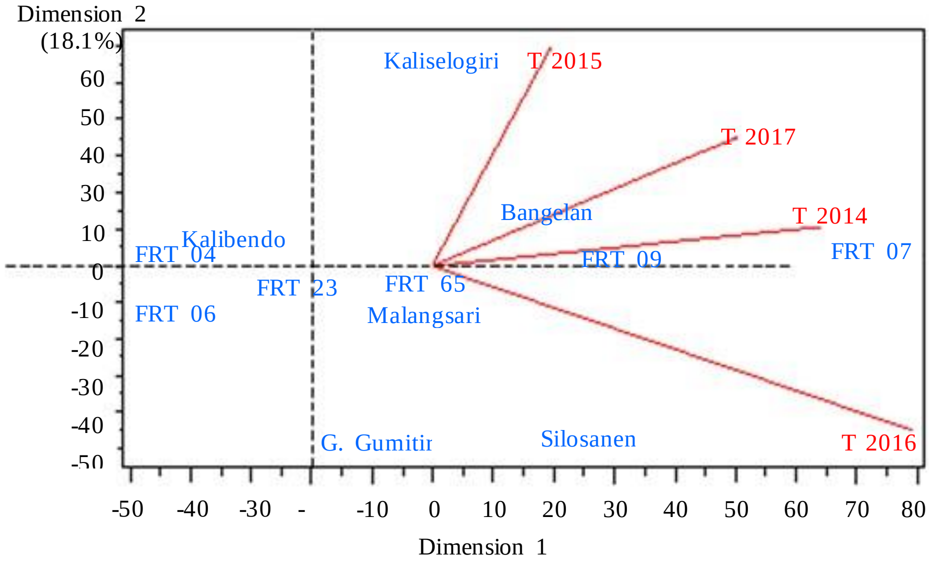


Figure 2. Biplot adaptability of Robusta clones tested by location and yield for four years period

Based on the results of the biplot analysis, it can be explained that the interaction among clones, locations and period (year) based on the yield of 4 harvest periods, the locations with wide adaptation are Kaliselogiri and Malangsari plantations which are on coordi- nate point (zero point). FRT 65 has a specific adaptation at the Malangsari plantation. However, in locations that have positive specific adaptations such as in Bangelan and Silosanen which have better yield compared to other locations. G. Gumitir and Kalibendo plantations show a specific negative adap- tation or unfavorable locations for planting the tested clones, although the location is quite well planted with FRT 04 clone. The resulting red line shows the annual produc- tion rate which is influenced by location and clone that have been observed in several locations in East Java. However year 2016 is the

Based on the multivariate biplot, the interaction of clones with location of Bangelan approaches zero point as coordinate point, meanwhile the clones of FRT 09 and FRT 65 are clones that have wide and stable adapta- tion in each location. However, FRT 07 shows specific high adaptations in each location. Clones that are outside or far from the coordi- nates or away from the arrow of the zero point indicate that the clone show better perfor- mance in term of yield at different locations, as shown in Figure 3.

Each clone tested in a different area will produce differently, because each clone has a different genetic traits interact with envi- ronment even though it comes from the same species. Level of yield of a plant is highly dependent on the environmental condition where the genotype is planted (Sujiprihati *et al.*, 2006). Mut *et al.*

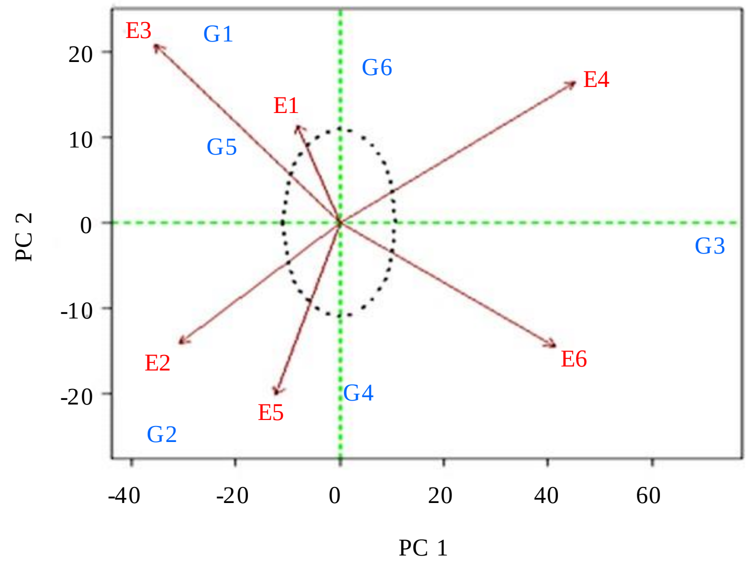


Figure 3. AMMI biplot on Robusta coffee production affected by interactions of several clones and locations in East Java

Notes: Genotype code: FRT 04 (G1), FRT 06 (G2), FRT 07 (G3), FRT 09 (G4), FRT 23 (G5), FRT 65 (G6). Environment code: Bangelan (E1), Gunung Gumitir (E2), Kalibendo (E3), Kaliselogiri (E4), Malangsari (E5), Silosanen (E6).

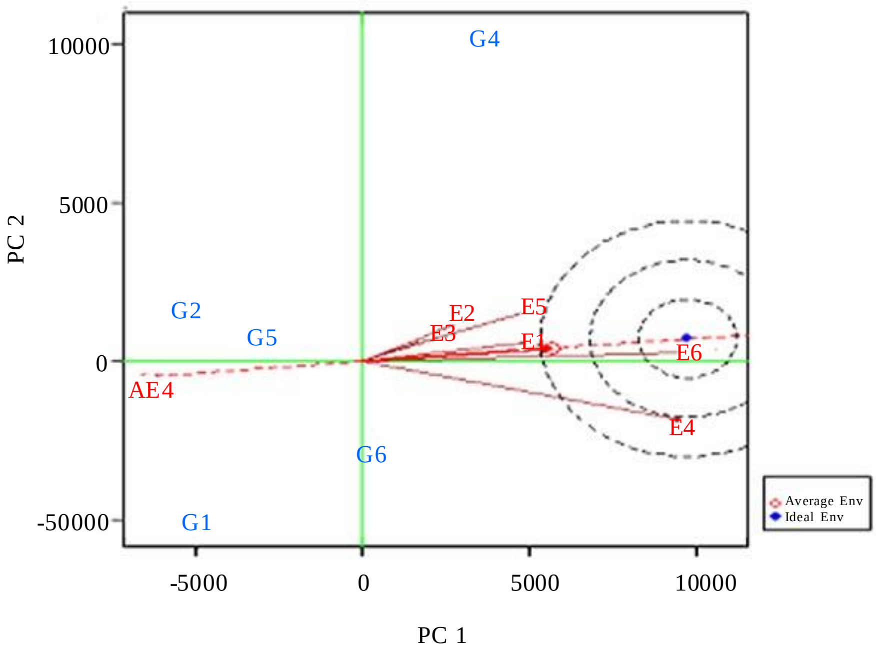


Figure 4. Ideal environmental biplot for estimating the yields of Robusta coffee clones tested when planted in six coffee plantations in East Java

Notes: Genotype code; FRT04 (G1), FRT06 (G2), FRT07 (G3), FRT09 (G4), FRT23 (G5), FRT65 (G6). Environment code; Bangelan (E1), Gunung Gumitir (E2), Kalibendo (E3), Kaliselogiri (E4), Malangsari (E5), Silosanen (E6).

Annual coffee production component is affected by the environmental changes due to variation in location and time (year) as demonstrated by the multilocation test carried out in this study (Figure 3). High variability in macro environments will result in very high diversity in the growing conditions (Satoto *et al.*, 2009). According to Nur (2000), coffee crop production shows fluctuation patterns which is strongly influenced by annual weather conditions. The influence of weather can be analyzed using population data and the composition of productive trees fertilized in the field.

Figure 4 presents the results of environment and genotype interactions using AMMI analysis. Data obtained from coffee plantations of Silosanen and Kaliselogiri shows that the two plantations located in the circle sector of multivariate data analysis patterns. These findings reveal that both environments are suitable locations for planting the clones that are in the positive line for estimating the yield

## CONCLUSIONS

FRT 07 and FRT 09 clones are the best clones in term of production and are able to adapt with microclimate conditions of the experimental sites of coffee plantations in East Java. The two clones have more stable results in coffee yield compared to other clones and have interaction between locations and clones tested annually. Relatively high produc- tion were obtained in Bangelan and Gunung Gumitir which may be related with rather

## ACKNOWLEDGEMENT

The authors wish to express their appre- ciation to the Directors of PTPN XII and PT. Kalibendo for their permission to use their coffee gardens for this study. A special thanks to the managers of Silosanen, Gunung Gumitir, Malangsari, Kaliselogiri, Bangelan, and Kalibendo coffee plantations for providing facilities during field works. We are also grate- ful to one of the editor (JBB) for carefully improving the manuscript.

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