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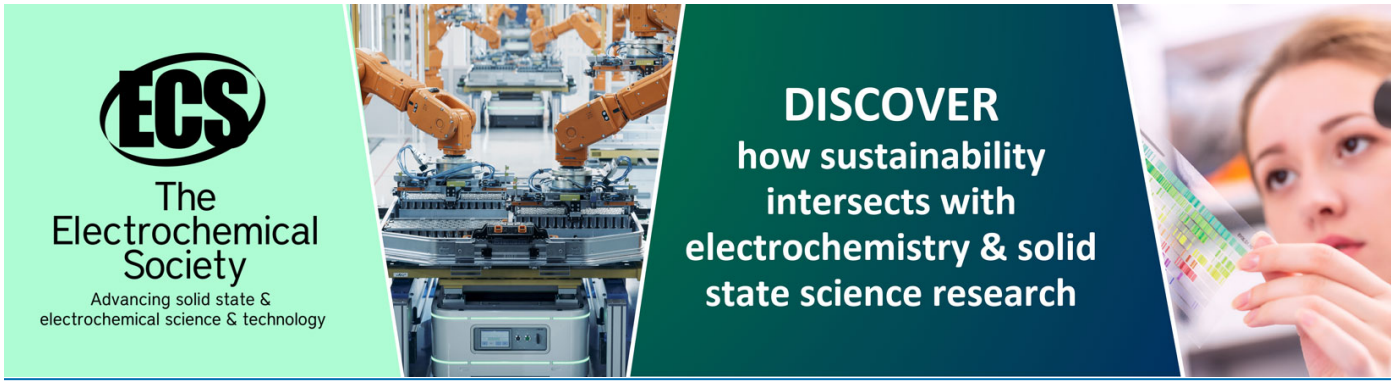

Components of genetic of coffee leaf rust symptoms in genotypes of Arabica coffee (*Coffea arabica* L.)

S Malau* and M R Sihotang

Faculty of Agriculture, Universitas HKBP Nommensen, Jalan Sutomo 4-A, Medan 20234, Indonesia.

E-mail: *sabam.malau@uhn.ac.id

Abstract. Coffee is a source of income for 100 thousand coffee farmers (households) in the province of North Sumatra, Indonesia. Rust on leaf of coffee (RLC) caused huge loss in income and jobs in coffee producing countries recently. This study was aimed to study genetic components of RLC in genotypes of coffee of Arabica. This research was carried out on the garden of the Agriculture Faculty of Universitas HKBP Nommensen, Medan, Indonesia. Seven genotypes were tested for its resistance. Randomized complete blocks design was used. The result revealed that Genotype P_5 from Dairi district and P_7 from Toba Samosir district had moderate and high resistance against RLC, respectively. Genotypic variation, advance of genetic and coefficient of heritability in severity of rust on leaf (SRL) were high. RLC parameter were not correlated one another. Based on the high resistance of P_7, genotypes performing high resistance could be found among Arabica coffee populations in North Sumatra province.

1. Introduction

RLC caused by fungus *Hemileia vastatrix*. RLC caused a huge economic loss in amount of $3.2 billion and job loss in amount of 1.7 million jobs in coffee producing countries [1]. Based on the results of a survey in several areas in North Sumatra, leaf rust severity (SRL) in *Coffea arabica* L. ranged from 1-45% (averaged around 14%) [2,3].

The government and the people of North Sumatra need to take anticipatory actions as early as possible so that RLC does not threaten the sustainability of coffee production. In Indonesia, Province of North Sumatra was the biggest producer of coffee of Arabica in 2018 [4]. In this province, there were 116 thousand of coffee farmers. They produced 63 thousand tons of green beans. There were 76 thousand hectares of coffee field located at hifh land.

Resistant cultivars, agronomic, chemical and biological treatment can be used to control the spread of fungus *H. vastatrix* and severity caused by this fungus [5,6]. Cultivation of resistant cultivar is the best solution. To create a resistant cultivar through crossbreeding method, however, is very difficult. Selection plant breeding method could be an alternative solution. Through this method, resistant genotypes may be found among populations of coffee plants that have genetic diversity in terms of resistance to *H. vastatrix*. The research aim was to study genetic components of RLC in genotypes of coffee of Arabica.

2. Materials and methods

Full ripe red fruits of genotypes of Arabica coffee namely P_1, P_2, P_3, P_4, P_5, P_6 and P_7 from seven districts of province North Sumatra were proceeded to produce seedlings in the green house. These seedlings were then planted at the research field of Nommensen HKBP University, Medan, Indonesia. After inoculation with urediniospores of *H. vastatrix*, RLC parameters namely incidence of rust on branch (IRB), incidence of rust on leaf (IRL), and severity of rust on leaf (SRL) were observed. Randomized complete block design using genotype as experimental units with three replications was used [7]. Variance analysis was conducted [8] (Table 1).

Table 1. Variance analysis [8].

Variation source	Degree of freedom	Expected mean squares	Mean squares	F-ratio	Estimated variance component	Estimated variance component (%)
Block	b-1		$MESQ_1$	$MESQ_1$ /$MESQ_3$		
Genotype	g-1	$\sigma^2_E + r\sigma^2_G$	$MESQ_2$	$MESQ_2$ /$MESQ_3$	VAR_G = ($MESQ_2$ - $MESQ_3$)/b	(VAR_G/VAR_T) x 100
Error	(b-1) (g-1)	σ^2_E	$MESQ_3$		VAR_{Error} = $MESQ_3$	(VAR_{Error}/VAR_T) x 100
Total	(bg)-1				$VAR_T = VAR_G + VAR_{Error}$	100

IRB, IRL dan SRL were tested for the 5% level of significance. Variation coefficient (%) was (($MESQ_3$)$^{0.5}$/grand mean) x 100%, coefficient variation of genotype (CVG) was (($VAR_G^{0.5}$)/phenotypic average) x 100%, estimated variance component of phenotype (VAR_P) was $VAR_G + VAR_E$, and coefficient of variation of phenotype (CVP) was (($VAR_P^{0.5}$)/phenotypic average) x 100% [9]. Heritability (H^2_{bs}) was VAR_G/VAR_P, advance of genetic (AG) was (i)(VAR_P)$^{0.5}$(H^2_{bs}), advance of genetic in phenotypic average (AGM) = (AG/phenotypic average) x 100% whereby i = 2.063 at 5% of intensity of selection [10]. CVG, CVP and AGM was defined as low (<5%), moderate (5-10%) and high (>10%) [11]. H^2_{bs} was defined as low (<40%), moderate (40-60%) and high (>60%) [11].

IRB, IRL and SRL as parameters of RLC were observed at four years old plants. Observation was done twice namely in March and November. Average value of these two observations was used then for the statistical analysis. IRB (%) was counted as percentage of the infected branch from total branches. A branch was defined as infected if it had one infected leaf on the underside of a leaf. Observation was conducted on all branches. IRL (%) was percentage of leaves that were infected by rust of total number of leaves on the branch infected by rust. All infected plants were observed. One branch infected by rust from the most upper, one from middle and one from the lowest part of a plant were chosen to determine IRL per plant. All leaves of these sample branches were observed. SRL (%) was percentage of leaf area that were rusted. To calculate averaged leaf rust severity of a plant, all rust infected leaves used in determining IRL were observed. A diagrammatic scale was used for assessment of SRL of a leaf [12]. Genotype showing SRL of >15, >5-15, >0-5, and 0 % was said as a low, moderate, high, and full resistant genotype, respectively [13].

3. Results and discussion

IRB showed significant genotypic differences (Table 2). IRL of genotype showed significant differences (Table 3). Genotypic different RLC was highly significant (Table 4).

Table 2. Incidence rust on branch.

Mean squares of replication	90.4
Mean squares of genotype	212.7*
Mean squares of error	46.6
F-ratio for genotype	4.6
VAR_G	55.4
VAR_E	46.6
VAR_P	101.9
CV (%)	15.6

Table 3. Incidence rust on leaf.

Mean squares of replication	2.0
Mean squares of genotype	87.8*
Mean squares of error	25.5
F-ratio for genotype	3.5
VAR_G	20.8
VAR_E	25.5
VAR_P	46.2
CV (%)	15.9

Table 4. Severity rust on leaf.

Mean squares of replication	0.2
Mean squares of genotype	173.9**
Mean squares of error	8.4
F-ratio for genotype	20.7
VAR_G	55.2
VAR_E	8.4
VAR_P	63.6
CV (%)	15.0

P_6 had the lowest IRB (Table 5). P_5 showed the lowest IRL. P_7 performed the lowest SRL. P_5 and P_7 performed moderate and high resistance, respectively, which indicated that resistant genotypes could be found among Arabica coffee populations that grow in various areas of province of North Sumatra.

Table 5. RLC parameter of genotypes.

Genotype	RLC parameter		
	IRB (%)	IRL (%)	SRL (%)
P_1	44.40 a-e	32.73 a-c	22.20 a-d
P_2	49.07 ab	29.50 cd	22.60 a-c
P_3	45.90 a-d	39.47 a	26.37 a
P_4	53.40 a	38.43 ab	21.67 a-e
P_5	33.07 ef	25.67 c-g	14.33 f
P_6	31.03 fg	26.97 c-f	24.13 ab
P_7	48.57 a-c	29.40 c-e	4.30 g
$LSD_{0.05}$	12.14	8.98	5.16

Note: The means with the same letter were not significantly different for the 5% level of significance test.

The result of this experiment showed high genotypic variation (Table 6) which was in line with the result of a survey conducted by [13] on Arabica coffee population growing in several districts of North Sumatera province. This experiment research and the survey revealed a high genetic advance in SRL of populations. High genotypic variation and high genetic advance in SRL are the basis for selection breeding for resistance against RLC pathogen. Selection based on SRL could be easy to carry out due to high phenotypic variation of SRL (41.16%). With a high heritability coefficient, SRL will be passed on to the progeny, meaning that if a plant with low SRL is selected, the progeny will also have a low SLR. This heritability coefficient in the broad sense (H^2_{bs}) was high because genotypic variance (VAR_G) contains the variance of the interaction of the genotype with the environment [14].

The result showed that IRB, IRL and SRL had no correlation one another (Table 7). IBR and IRL are parameters of dispersal, and SRL is indicator of severity. Because there is no correlation between dispersal and severity, the increase in the level of dispersal is not simultaneously with the increase in severity, and vice versa.

Table 6. Genetic components of RLC parameter.

	RLC parameter		
	IBR	IRL	SRL
CVG (%)	17.05	14.37	38.34
CVP (%)	23.14	21.43	41.16
H^2_{bs} (%)	73.70	67.05	93.15
AG	15.35	9.41	15.32
AGM (%)	35.18	29.64	79.10

Table 7. Correlation coefficient, coefficient of determination, and regression between RLC parameter.

RLC parameter				
Y	x	r	r^2	Regression
IRL	IBR	0.674ns	0.454	Y = 12.86 + 0.43x
SRL	IBR	-0.060ns	0.004	Y = 21.74 - 0.05x
SRL	IRL	0.438ns	0.192	Y = -0.19 + 0.62x

This experiment showed that the resistant genotypes could be found among the existing coffee populations that grow in North Sumatra province. It could be due to its the rich genotypic variability in some phenotypes as resistance to RLC [3], morphologies [11], and adaptability to changing climate [15].

4. Conclusion

The experiment result showed that genotype P5 and P7 performed moderate and high resistance, respectively, which together with the high genotypic variation indicated that resistant genotypes may be found among Arabica coffee populations that grow in various areas of North Sumatra. Genotypes performed high genetic advance and high heritability coefficient in SRL. SRL had no significant correlation with IBR and IRL.

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