

Germination performance of *Coffea arabica* L. genotypes from different altitude, precipitation and temperature of seeds producing farms in Sumatera Utara of Indonesia

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Abstract. Genotypes of Arabica coffee could perform different ability in seed germination. Biochemical contents of seeds could influence germination ability of seeds. Many studies reported that environment of seed producing site such as altitude, precipitation and temperature could affect amount of biochemical contents of seeds. However, germination ability of seeds of arabica coffee growing in different altitude and different climate zones of Sumatera Utara was not yet investigated. This research tested the effect of genotypes and these factors. Seven genotypes from seven different climate zones in seven districts of Sumatera Utara were tested for germination ability using randomized complete block design. The result showed that genotypes were significantly ($\alpha = 0.05$) and highly significantly different ($\alpha = 0.01$) in number of days to reach 80 % germination, percentage of germination, height of cotyledon, and height of the first leaf. Number of days to reach 80 % germination showed a significant negative correlation ($r = -0.930^{**}$) with percentage of germination but a significant positive correlation ($r = 0.759^{*}$) with altitude of farms. It could be concluded that Arabica coffee genotypes affected seed germination ability. Seed germination ability was more affected by elevation of seed producing location rather than by precipitation and temperature.

1. Introduction

Phenotype of plants depends on genotype (G), environment (E) and their interaction (GxE). Coffee genotype and environment such as altitude, precipitation, temperature, year, and location during bean development affect chemical contents of seed of coffee, bean weight, bean size, and taste quality [1-10]. The biochemical contents include caffeine, trigonelline, fat, sucrose, chlorogenic acids, ketones, aldehydes, phenolic compounds, norisoprenoids, pyrazines, and terpenes. Genotypes might produce different amount of the same chemicals at different location or at different year (Y) due to GxE or GxExY interaction [9]. The more the altitude is, the higher the content of sucrose in the seeds [11].

In North Sumatra Province of Indonesia, Arabica coffee were planted in Districts of Humbang Hasundutan, Simalungun, Pakpak Bharat, Samosir, Dairi, Tapanuli Utara, Toba Samosir, Karo, Mandailing Natal and Deli Serdang. In these provinces, coffee farms of arabica coffee located at various altitudes (700-1800m asl) and various climate zones (A1, B1, C1, D1, D2, E1, E2 dan E3).



Based on it, seeds of Arabica coffee may have different amount of the biochemical substances. Since biochemical substances of seeds must be changed into energy, amino acids, fat, and enzymes during germination process [12], differences in amount of biochemical substances in coffee seeds may cause different germination ability. However, information on germination ability of seeds of Arabica coffee growing in different altitude and different climate zones of Sumatera Utara was not yet available. The goal of this research was to determine seed germination ability of arabica coffee found at coffee growing areas in Sumatera Utara. The hypotheses were that genotypes could be significantly different in germination abilities as well as that germination parameters could perform significant correlation with altitude, precipitation and temperature of the seed producing farm.

2. Materials and Methods

Seven districts were chosen based on level of coffee production level and accessibility. Data of length of the rainy season and the precipitation of the climate zones are presented in Table 1.

Table 1. The length of rainy season and precipitation of the climate zones [13].

Climate zone	Length of rainy season (month)	Minimum precipitation (mm/year)	Maximum precipitation (mm/year)	Average precipitation (mm/year)
A1	10 (March - December)	3108	4388	3822
B1	8 (May - December)	2595	3104	2933
C1	5 (August - December)	1750	3957	2729
D1	4 (August - December)	1705	3085	2274
D2	3 (September - November)	1749	2409	1911
E1	2 (September - October)	1615	2145	1922
E2	2 (September - October)	1172	2233	1685

Then, one coffee farm in each district was selected based on the climate zones map of Sumatera Utara [13]. Data of the altitude of the selected farms of coffee was recorded by using Garmin GPS MAP 78s while data of the temperature of the selected farms were collected from districts statistics [14] (Table 2). In each selected farm, 200-400 coffee plants with age of 6-7 years were producing ripe fruits, having harvest frequency of once in two weeks, and performing shoot of bronze-colored leaves. Coffee plants of selected farms were growing without shade. According to information of the owner of the coffee farm, parental plant originated from the same climate zone. In each farm, all red riped fruits of ten best plants were harvested separately for germination test. Normal flat seeds were used for germination test [15]. Randomized complete block design with three replication was used [16]. Germination test was conducted in 2014-2015 in the green house of Agriculture Faculty of Universitas HKBP Nommensen, Medan. Parameters were: number of days after sowing to reach 80% germination (day), percentage of germination (%), height of cotyledon (cm), and height of the first leaf as it opened (cm). Germination percentage, cotyledon height, and the first leaf height were recorded at age of 90 days after sowing. Comparison between treatment means was conducted by using Fisher's LSD test. Besides, analysis of simple correlation coefficient and determination coefficient were also carried out.

Table 2. Districts, climate zone, genotype, altitude and temperature of selected coffee farms

Districts	Climate zone of selected coffee farms	Selected genotypes	Altitude of selected coffee farms (m)	Average temperature of selected coffee farms (°C)
Humbang Hasundutan	A1	HuA1	1122	23.3
Simalungun	B1	SiB1	1061	23.1
Pakpak Bharat	C1	PbC1	897	22.9
Samosir	D1	SaD1	1323	22.5
Dairi	D2	DaD2	1603	21.8
Tapanuli Utara	E1	TaE1	1221	23.6
Toba Samosir	E2	ToE2	956	23.6

3. Result and Discussion

The genotypes were significantly different ($\alpha = 0.05$) in number of days to reach 80% germination (Table 1). The genotypes performed highly significantly different ($\alpha = 0.01$) in percentage of germination, height of cotyledon, and height of the first leaf. Genotype TaE1 reached 80% germination in 59.00 days while DaD2 reached 80 % germination in 65.00 days (Table 2). The highest percentage of germination (98.00 %) was shown by PbC1 while the lowest one (87.33) was performed by DaD2. HuA1 had the highest cotyledon (6.40 cm) while SaD1 showed the lowest one (5.37 cm). The highest first leaf (12.6 cm) was performed by SiB1. SaD1 showed the lowest first leaf (9.67 cm). Number of days to reach 80 % germination had a significant negative correlation ($r = -0.930^{**}$) with percentage of germination as well as a significant positive correlation ($r = 0.759^{*}$) with elevation of farm of seed source (Table 5). Percentage of germination and height of cotyledon significantly and negatively correlated with elevation of farm of seed source.

Table 3. Mean square of number of days to reach 80% germination, percentage of germination, height of cotyledon, and height of the first leaf.

Parameter	Replication (df = 2)	Genotype (df = 6)	Error (df = 12)	Coefficient of variation (%)
Number of days to reach 80% germination (day)	0.3333	15.7143*	3.6667	3.11
Percentage of germination (%)	4.6190	36.7143**	5.2857	2.48
Height of cotyledon (cm)	0.0186	0.5408**	0.0891	5.02
Height of the first leaf (cm)	0.1600	2.8727**	0.5522	6.71
$F_{0.05}$		3.00		
$F_{0.01}$		4.82		

f = degree of freedom, MS = mean of square, ns = not significant, * = significant at $\alpha = 0.05$; ** = significant at $\alpha = 0.01$; $F_{0.05}$ = value of F tabular at $\alpha = 0.05$; $F_{0.01}$ = value of F tabular at $\alpha = 0.01$.

Table 4. Number of days to reach 80 % germination, percentage of germination, height of cotyledon, and height of the first leaf.

Climate zone of selected farms	District of selected farms	Selected genotype	N80 (day)	PGe (%)	HCo (cm)	HFL (cm)
A1	Humbang	HuA1	63.00 a-c	91.00 b-e	6.40 a	10.03 d-f
B1	Hasundutan	SiB1	60.67 b-d	94.33 a-c	6.20 a-c	12.60 a
C1	Simalungun	PbC1	59.33 d-f	98.00 a	6.33 ab	11.50 ab
D1	Pakpak Bharat	SaD1	63.67 ab	90.33 c-f	5.37 e-g	9.67 fg
D2	Samosir	DaD2	65.00 a	87.33 e-g	5.47 ef	11.47 a-c
E1	Dairi	TaE1	59.00 d-g	95.00 ab	5.70 c-e	11.20 b-d
E2	Tapanuli Utara	ToE2	60.67 b-e	92.33 b-d	6.13 a-d	11.03 b-e
LSD _{0.05}			3.41	4.09	0.53	1.32

N80 = number of days to reach 80 % germination (day), PGe = percentage of germination (%), HCo = height of cotyledon (cm), HFL = height of the first leaf opened (cm), LSD_{0.05} = least significant difference at $\alpha = 0.05$, the means in the same column which followed by common letters were not significantly different at $\alpha = 0.05$ level based on Fisher's LSD test.

Table 5. Simple correlation coefficient (r, above) and coefficient of determination (r^2 , below) among seedling parameters, precipitation, altitude and temperature.

	PGe (%)	HCo (cm)	HFL (cm)	AvP (mm)	MiP (mm)	MaP (mm)	Ele (m asl)	AvT (°C)
N80 (day)	-0.930** 0.865	-0.485ns 0.235	-0.424ns 0.180	0.070ns 0.005	0.207ns 0.043	0.065ns 0.004	0.759* 0.576	-0.751ns 0.564
PGe (%)	x	0.560ns 0.314	0.391ns 0.153	0.148ns 0.022	-0.057ns 0.003	0.231ns 0.053	-0.798* 0.637	0.581ns 0.338
HCo (mm)	x	x	0.265ns 0.070	0.631ns 0.398	0.472ns 0.223	0.603ns 0.364	-0.820* 0.672	0.576ns 0.332
HFL (mm)	x	x	x	-0.131ns 0.017	-0.014ns 0.0002	-0.257ns 0.066	-0.184ns 0.034	0.019ns 0.0004

$n = 7$, * = significant at $\alpha 0.05 = 0.754$, ** significant at $\alpha 0.01 = 0.874$; ns = not significant; N80 = number of days to reach 80 % germination (day), PGe = percentage of germination (%), HCo = height of cotyledon (cm), HFL = height of the first leaf as opened (cm), AvP = average precipitation at farms (mm), MiP = minimum precipitation at farms (mm), MaP = maximum precipitation at farms (mm), Ele = elevation of farms (m asl), AvT = Average temperature at farms.

This research revealed that genotypes were significantly different in germination ability in reaching 80 % germination (Table 1). This result agreed with [6]. The significant difference of genotypes in germination percentage (Table 1) was in contrary with [6]. Germination ability in reaching 80 % germination negatively affected percentage of germination but did not affect cotyledon height and the first leaf height (Table 5).

Elevation positively affected germination ability in reaching 80 % germination (Table 5). The higher the seed producing site was, the less the number of days. The cause might be the sucrose amount in the seeds as sucrose was converted into energy during germination. Amount of sucrose in the seed increased as elevation of seed producing farm increased [11]. Germination of coffee seed is indicated by radicle protrusion. It had been proven that both embryo growth and weakening of the endosperm cap controlled radicle protrusion [17]. However, no research findings were reported that

embryo development and endosperm cap are affected by elevation of seed producing farm. Hence, in the future it has to be researched.

No research findings can be found that could explain why the elevation is negatively correlated with cotyledon height and first leaf height. The cause might be the content of sucrose. As the faster the germination took place, the more the sucrose was used, the less the sucrose amounts was available to increase height of cotyledon and height of the first leaf. Consequently, elevation was negatively correlated with cotyledon height and first leaf height.

Precipitation at farms did not correlate with seed germination parameters (Table 5). The precipitation level (Table 1) could have provided the minimum and maximum need of water for seed development [18] so that all seeds had the same germination ability. In contrast to the formation of germination ability of seed, however, the optimal precipitation for seed production were 1500-2000 mm/year [19].

Temperatures of the seed producing farms did not correlate with seed germination parameters (Table 5). It might be because all genotypes grew at the range of the optimum temperatures (20-25 °C, Table 2) [15, 19-20] which could cause the same development of seed. Temperature at above 25°C had a large inhibitory effect by reducing photosynthesis [21].

For coffee breeding, the result of this research could have an implication. Elevation of seed producing site must be considered in selecting the best genotypes in seedling performance. However, because this research was conducted with nonfactorial experiment, GxE interaction was not able to be calculated. Hence, factorial experiment must be carried out in future research to evaluate GxE interaction.

4. Conclusion

This research revealed that genotypes affected germination ability of coffee seed. In comparison to precipitation and temperature of seed producing site, elevation had more effect on seed germination ability. Interaction of genotype and environmental factors was not investigated by this research. In the future, research is needed to study this interaction.

5. References

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