Jurnal Lahan Suboptimal : Journal of Suboptimal Lands
ISSN: 2252-6188 (Print), ISSN: 2302-3015 (Online, www.jlsuboptimal.unsri.ac.id)
Vol. 10, No.2: 140−149 Oktober 2021
DOI: 10.36706/JLSO.10.2.2021.522

Yield Components and Efficiency Index of Maize Yield: Relationship to Yields in Tidal Fields

Komponen Hasil dan Indeks Efisiensi Hasil Jagung: Hubungannya dengan Hasil di Lahan Pasang Surut

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(Received: 3 February 2021, Accepted: 17 September 2021)

Citation: Yustisia Y, Ratmini NPS, Amirrullah J, Juwita Y, Hutabarat YPAP, Atekan A. 2021. Yield components and efficiency index of maize yield: relationship to yields in tidal fields. *Jurnal Lahan Suboptimal : Journal of Suboptimal Lands.* 10 (2): 140−149. DOI: 10.36706/JLSO.10.2.2021.522.

ABSTRAK

Identifikasi keunggulan galur-galur jagung hibrida diperlukan untuk mendukung peningkatan produksi dan pengembangan jagung di lahan pasang surut. Penelitian bertujuan untuk mengidentifikasi karakter agronomi dan komponen hasil galur-galur jagung hibrida dan hubungannya dengan hasil dan efisien pupuk di lahan rawa pasang surut. Rancangan yang digunakan adalah Split Plot dengan tiga ulangan. Petak Utama adalah galur/varietas jagung hibrida (L39/MR4, MGOLD/G8, G28/MGOLD dan P27). Anak petak adalah Pupuk Komposit dengan 2 takaran yaitu 600 kg/ha dan 720 kg/ha. Pupuk Urea (50%), SP 36 dan NPK (100%) diberikan pada 10 hari setelah tanam (HST). Sisa Urea diberikan pada 30 HST, masing-masing 50% dan 58,33% pada perlakuan Pupuk Komposit 600 kg/ha dan 720 kg/ha. Kultur teknis yang diterapkan adalah olah tanah sempurna, jarak tanam 70 cm x 25 cm, pengairan dilaksanakan pada H/HST dan 15 HST, pengendalian gulma dan OPT secara optimal. Hasil penelitian menunjukan bahwa jumlah baris/tongkol merupakan peubah alternatif dalam mengidentifikasi galur/varietas jagung berdaya hasil tinggi dan efisien hara. Karakter ini berkorelasi erat dengan berat biji/tongkol (r = 0,94) dan Indeks Efisiensi Hasil Biji/IEHB (r = 0,84). Seluruh Genotipe efisien hara (IEHB > 1) kecuali G28/MGOLD (IEHB < 1). Pendekatan lainnya yang dapat digunakan untuk mengidentifikasi galur/varietas efisien pemupukan adalah peubah persentase penurunan hasil melalui persamaan regresi dengan IEHB (y = - 0,0104 x + 1,0426). Karakter jumlah baris/tongkol yang tinggi dapat dimanfaatkan sebagai tetua dalam program pemuliaan tanaman. Galur/varietas jagung sebagai komponen teknologi yang efisien dan produktivitas tinggi berkontribusi terhadap peningkatan produksi dan pengembangan di lahan pasang surut.

Kata kunci: galur jagung, korelasi dan regresi, pemupukan yang efisien

ABSTRACT

Identification of the advantages of hybrid maize lines is needed to support the increased production and development of maize in tidal fields. This study aimed to identify the agronomic characters and yield components of hybrid maize lines/varieties and their relationship with high yield and efficient fertilization in tidal fields. The design used was a Split Plot with three replications. The Main Plot was a hybrid maize line/variety (L39/MR4, MGOLD/G8, G28/MGOLD, P27). The subplots were Composite Fertilizer with 2 measures, namely 600 kg/ha and 720 kg/ha. The fertilizers of Urea (50%), SP 36 and NPK (100%) were given at 10 days after planting (DAP). The remaining Urea was given at 30 DAP, 50% and 58.33% respectively in the Composite Fertilizer treatment of 600 kg/ha and 720 kg/ha. The technical culture applied was optimum tillage with the 70 cm x 25 cm spacing, the irrigation being carried out at D/DAP and 15 DAP, the optimal control on the weed and Plant Pest Organisms. The result showed that the number of rows/cobs was an alternative variable in identifying maize lines/varieties with high yield and efficient fertilization. This character was closely correlated with seed/ear weight (r = 0.94) and Grain Yield Efficiency Index/GYEI (r = 0.84). All Genotypes were nutrient efficient (GYEI > 1) except G28/MGOLD (IGYEI < 1). Another approach used to identify efficient fertilization lines/varieties was the variable percentage of yield reduction through regression equations with GYEI (y = - 0.0104 x + 1.0426). The character of high number of rows/cob could be used as genetic material in plant breeding programs. The lines/varieties as a component of efficient technology and high productivity would contribute to increase production and development of maize in tidal fields.

Keywords: corn lines, correlation and regression, efficient fertilization

INTRODUCTION

The yield component is one of the important variables used in estimating maize yield. Some of the yield components were the number of cobs, weight of cobs, number of seeds, and weight of seeds harvested (Echarte et al., 2013; Marcovic et al., 2017; Tandzi & Mutengwa, 2020). The performance of maize yield components is largely determined by genotype (Liu, 2015; Chen et al., 2016), fertilization (Basa et al., 2016; Sinaga et al., 2020), and agro-ecosystem (Tucker et al., 2020; Tabakovic et al., 2020).

Tidal swamp land is one of the potential agro-ecosystems as a source land to cultivation maize for maize. The characteristics of tidal areas include, among others, a wet climate with the rainfall of more than 2000 mm/year (Ritung et al., 2015). In wet climate areas with high rainfall, the availability of Ca, Mg and K, and soil acidity tends to be low tends to be low (Putra & Hanum, 2018). Based on these characteristics, the swampy areas are classified as suboptimal ones. the low tidal land soil fertility accompanied by conditions high soil Fe and Al contents and acid to very acidic reaction (Arsyad et al., 2014; Wijanarko & Taufiq, 2016; Fahmi et al., 2018).

The performance of plant growth and yield is largely determined by the interaction among the genetic factors, environmental factors and management factors (Worku et al., 2016; Fernandez et al., 2020; Eze et al., 2020; Lilian & Charles, 2020). In terms of management factors, the effectiveness of fertilizer technology in increasing land productivity is very needed. It, among others, highly depends on the price of fertilizer. The problem faced is that the price of fertilizer is expected to continue to increase (Zaini, 2012). This is due to the impact of the reintroduction of the reduction in fertilizer subsidies by the government since 2010. The impact requires farmers to manage fertilizers efficiently. On land with low productivity, including tidal areas, it was absolutely necessary to carry out proper fertilization. Excessive fertilization results in low fertilizer use efficiency and environmental pollution. On the other hand, applying too low fertilizer results in ineffective fertilization so that the crop production was not optimal. Apart from the proper fertilizer management, other efforts that can be made to increase the tidal land productivity and maize productivity are through the use of high yielding varieties (Andayani et al., 2014) and efficient fertilizers. The agronomic characteristics and yield components will determine the yield potential of a variety. The yield component-based variety selection to produce high yield varieties was more effective in breeding programs. This study aimed to identify the agronomic characters and yield components of hybrid maize lines/varieties and their relationship with high yield and efficient fertilization in tidal fields.

MATERIALS AND METHODS

The study was conducted in tidal swampy lands, Pinang Banjar Village, Sungai Lilin Subdistrict, Musi Banyuasin (MUBA) District from January to December 2019. The experiment used a Split Plot Design with 3 replications. The Main Plot Treatment consisted of 3 hybrid maize lines (L39/MR4, MGOLD/G8 and G28/MGOLD) and one comparing variety (P27). The treatment of subplots comprised 2 dosages of composite fertilizer, namely 600 kg/ha of NPK-Urea-SP 36 and 720 kg/ha of NPK-Urea-SP 36 (Table 1). The seeds of 3 hybrid maize lines of L39/MR4, MGOLD/G8 and G28/MGOLD derived from the Cereal Research Institute, Indonesian Agency for Agricultural Research and Development (IAARD) and the comparing variety of P27 from the private product. The technical culture applied was optimum soil cultivation, 1 seed per hole, 70 cm x 25 cm spacing, and irrigation being carried out before planting and when the maize getting 15 days after planting (DAP). Control of diseases, weeds, and pests was carried out optimally. Downy mildew was prevented by using fungicides with metalaxyl active ingredients. The dose of fungicide was 5 g metalaxyl/kg seed. Weeds were controlled using herbicide with the active ingredient Atrazine 300 g/l + topramezone 10 g/l. Herbicide dose of 2 l/ha was applied at 14−21 DAP. The stem borer and cob borer were controlled using an insecticide with the active ingredient BPMC 450 g/l + diazinon 300 g/l. Insecticides were applied at a rate of 1.5−2.0 l/ha**.** The soil characteristics in the assessment location were medium soil P, medium soil K, soil pH 5−6 (slightly acidic) and low organic C. Dolomite was used at a doses of 1,000 kg/ha given 7 days before planting. The manure was given at planting at a doses of 2,000 kg/ha as cover the planting holes.

The observed data included: (1) growth data: plant height, corncob height, (2) yield components: corncob length, corncob diameter, number of rows/cobs, number of seeds/rows and yield/plant (weight of seeds/cob, moisture content of seed 15%), and (3) value of Grain Yield Efficiency Index (GYEI). The variety was efficient if it has an GYEI value > 1. The GYEI value was calculated using the formula approach of Fageria et al. (2015) as follows:

$$GYEI = \frac{HGHrL / HRHrL}{HGHrT / HRHrT}$$

GYEI	:	Grain Yield Efficiency Index
HGHrL	:	The yield of the varieties tested under low nutrient conditions
HRHrL	:	Average yield of varieties under low nutrient conditions
HGHrT	:	The yield of the varieties tested under high nutrient conditions
HRHrT	:	Average yield of varieties in high nutrient conditions

The data were analyzed by means of variance. The regression and correlation tests were carried out to determine the relationship between: (a) the character of the yield components and the results, and (b) between the observed variables (the percentage of yield reduction and the grain yield efficiency index/GYEI).

Table 1. Fertilization dosage and application

Treatments/ Fertilizers	Dose (kg/ha)	Application (kg/ha)	
		10 DAP	30 DAP
A. Composite (NPK-Urea-SP 36)	600		
NPK 15:15:15	300	300	0
Urea	250	125	125
SP 36	50	50	0
B. Composite (NPK-Urea-SP 36)	720		
NPK 15:15:15	360	300	60
Urea	300	125	125 + 50
SP 36	60	50	10

RESULTS AND DISCUSSION

Results of Normality Test, Homogeneity Test and ANOVA Test

The results of the normality test using the Kolmogorov-Smirnov method and the results of the variance homogeneity test using the Levene method on the observed research variables showed a significance value of p > 0.05 (Table 2). The result indicated that the research data were normally distributed and had a homogeneous variety between treatments.

The ANOVA test results showed that all variables were not influenced by the fertilizer and interaction factors with a p value of more than 0.05 (Table 3). The variables influenced by the variety factor were the number of rows/cobs, the number of seeds/rows and the height of the cobs (p < 0.05). The differences between the varieties in each variable were presented in Table 4. These results showed that the variable differences in the number of rows/cobs, number of seeds/rows and the height of cobs were highly influenced by the genetic factors. The p value > 0.05 on the fertilizer and interaction factors showed that all tested lines/varieties had the same response to fertilization.

The weight of the seeds/cobs was the variable that determines the productivity of maize. The highest seed/cobs weight was achieved by the P27 comparing variety followed by the L39/MR4 and MGOLD/G8 and G28/MGOLD. The P27 variety was one of the hybrid maize varieties relatively developed in the tidal fields of South Sumatra. The weight of the seeds/cobs of the tested three hybrid maize lines was not significantly different from the P27 result (Table 4). The relatively similar results between the tested three lines/varieties with the P27 comparing variety indicated that these three lines were alternative lines for further study and had the opportunity to be developed in tidal fields.

Table 2. The results of the normality test and the results of the variance homogenity test of variety

Variables	Normality Test		Variance Homogeneity Test			
	Kolmogorov-Smirnov Z	Signi-ficance	F	df1	df2	Signi-ficance
Corncob Length	0.757	0.615	2.568	7	16	0.056
Corncob Diameter	0.789	0.562	3.262	7	16	0.054
Number of Rows/Cobs	0.757	0.616	1.704	7	16	0.178
Number of Seeds/Rows	0.668	0.764	1.496	7	16	0.238
Corncob Notch Height	0.867	0.440	3.999	7	16	0.050
Plant Height	1.039	0.231	1.902	7	16	0.136
Weight of Seeds/Cob (Moisture Content of Seed 15%)	0.587	0.881	1.326	7	16	0.301

Table 3. Analysis of variance

Variables	Significance		
	Varieties	Fertilizer	Interaction
Corncob Length	0.197	0.389	0.860
Corncob Diameter	0.502	0.226	0.672
Number of Rows/Cobs	0.000	0.168	0.518
Number of Seeds/Rows	0.000	0.067	0.745
Corncob Notch Height	0.037	0.531	0.963
Plant Height	0.642	0.706	0.438
Weight of Seeds/Cob (Moisture Content of Seed 15%)	0.604	0.286	0.801

Table 4. Character performance of maize lines/varieties

Variables	Corn Lines/Varieties			
	L39/MR4	MGOLD/G8	G28/MGOLD	P27
Plant Height (cm)	177.278[a]	188.250[a]	186.307[a]	186.668[a]
Corncob Notch Height (cm)	71.418[a]	83.140[ab]	88.833[b]	87.002[b]
Corncob Length (cm)	22.750[a]	23.653[a]	22.375[a]	23.597[a]
Corncob Diameter (cm)	50.188[a]	48.008[a]	48.302[a]	51.052[a]
Number of Rows/Cobs	16.695[b]	16.065[b]	14.137[a]	16.445[b]
Number of Seeds/Rows	32.888[a]	36.333[b]	41.168[c]	35.695[b]
Weight of Seeds/Cob (Moisture Content of Seed 15%) (g)	179.268[a]	173.933[a]	168.497[a]	179.727[a]

Correlation between Plant Characteristics and Yield

The number of the rows/cobs was one component of the yield. This component was a determining parameter for maize productivity (Munawar et al., 2013). Milander (2015) reported that there was a very significant positive correlation between the number of rows/cobs and maize yield. The research result of Jatto et al. (2015) showed that the highest correlation coefficient value was obtained in the relationship between the number of rows/cobs and the yield. The correlation among the plant height, cob height, cob length and number of seeds/cobs respectively with the seed/cob weight was presented in Table 5. In this study, only two characters namely, number of rows/cob and cob diameter showed significant and highly significant positive correlation, respectively with grain yield at both genotypic and phenotypic levels, indicating that these two characters are probably the most important yield characters.

The characters that showed a close relationship with the weight of seeds/cobs were cob diameter ($r = 0.8511$) and number of rows/cob ($r = 0.9438$). There was closeness of the relationship between cob diameter and yield in line with the study results of Ali and Ahsan (2015), Adhikari et al. (2018), Mousavi and Nagy (2021), and Yahaya et al. (2021). The cob diameter was a variable that determines the number of rows/cobs and the number of seeds/rows. Other reports state that there was a highly positive correlation among diameter of the cob and the number of rows/cobs and the number of seeds/rows Jatto et al. (2015). The results of the studies put forward that the bigger the diameter of the cob, the more the number of seeds/row, the more the number of seeds/cob, the higher the weight of the seeds (yield/plant).

Table 6 showed the regression of the characters of plant height, cob height, cob length, cob diameter and number of seeds/rows, each with seed/cob weight with negative/positive seed/cob weight was not significant ($p > 0.05$). The regression analysis showed that an important character determining the yield of hybrid maize tested in this study was the number of rows/cob ($p = 0.056$). The data showed a positive linear relationship between the number of rows/cobs and the weight of seeds/cobs shown by the equation of $y = 4.2863 x + 107.48$ (Figure 1).

Table 5. Correlation of growth characters and yield component characters with yield of hybrid maize lines/varieties

Variables	Weight of Seeds/ Cob	Plant Height	Corncob Notch Height	Corncob Length	Corncob Diameter	Number of Rows/ Cobs	Number of Seeds/Rows
Weight of Seeds/Cob	1	-0.4641	-0.5495	0.4983	0.8511	0.9438	-0.9078
Plant Height	-0.4641	1	0.8881	0.4634	-0.4243	-0.4096	0.6264
Corncob Notch Height	-0.5495	0.8881	1	0.1267	-0.2646	-0.6380	0.8156
Corncob Length	0.4983	0.4634	0.1267	1	0.2046	0.6171	-0.4000
Corncob Diameter	0.8511	-0.4243	-0.2646	0.2046	1	0.6300	-0.5972
Number of Rows/Cobs	0.9438	-0.4096	-0.6380	0.6171	0.6300	1	-0.9644
Number of Seeds/Rows	-0.9078	0.6264	0.8156	-0.4000	-0.5972	-0.96437	1

Table 6. Regression between growth characters and yield component characters with yield

Regression	Regression Equation	Significance
Plant Height and Seed/Cob Weight	y = -4925 x + 266.29	$p > 0.05^{ns}$
Corncob Notch Height and Seed/Cob Weight	y = -0.3706 x + 205.97	$p > 0.05^{ns}$
Corncob Length and Seed/Cob Weight	y = -4.1548 x + 79.406	$p > 0.05^{ns}$
Corncob Diameter and Seed/Cob Weight	y = 3.0520 x + 24.627	$p > 0.05^{ns}$
Number of Seeds/Rows and Seed/Cob Weight	y = -1.3919 x +226.1912	$p > 0.05^{ns}$

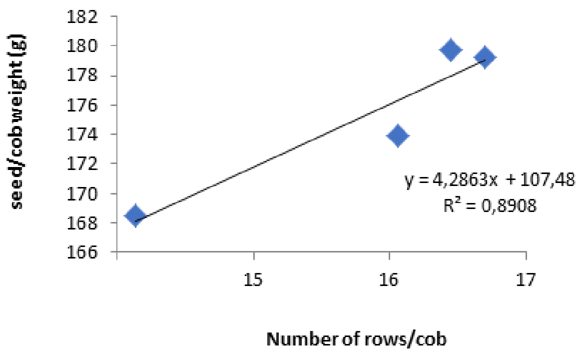

Figure 1. Number of rows/cob and seeds/cob weight regression

Correlation and Regression of Plant Character and GYEI

The input-efficient lines/varieties are one of the most likely technologies to be adopted by users. One indicator of an input-efficient variety was the value of the seed yield efficiency index (GYEI). According to Fageria (2015), the input efficient varieties have an GYEI value of more than 1. Table 7 showed all the tested lines/varieties had an GYEI value of more than 1, except the G28/MGOLD lines. The highest GYEI value was achieved by the MGOLD/G8 lines, followed by the P27 and L39/MR4 lines.

The very tight regression between the percentage reduction in yield with GYEI was presented in Figure 2. The lower the yield reduction in the lower fertilizer package (composite fertilizer of NPK 15:15:15-Urea-SP 36 (600 kg) compared to the high fertilizer package (composite fertilizer of NPK 15:15: 15-Urea-SP 36 (720 kg), the higher the GYEI value was. The MGOLD/G8 lines had the lowest yield reduction percentage and the highest GYEI value, followed by varieties of P27 and

L39/MR4. It was in contrast to the G28/MGOLD lines. Consequently, the percentage of yield reduction was one of the determining characteristics in the identification of efficient fertilization of maize lines/varieties. The study used various inputs (low-medium-high) to obtain site-specific components/technology packages that could be carried out in various potential agroecosystems in South Sumatra Province. Therefore, the input efficient maize lines/varieties could be identified through the approach of yield reduction percentage value. Figure 2 shows that the efficient lines/varieties were found out through the percentage of yield reduction with the regression equation of y = - 0.0104 x + 1.0426.

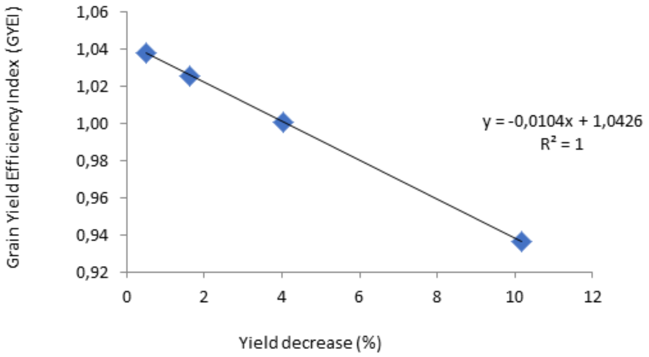

Figure 2. Yield decrease and GYEI regression

Table 7. Grain yield efficiency index value of hybrid maize lines/varieties

Lines/ Varieties	Seed/Cob Weight (g)			Average Seed/Cob Weight (g)			GYEI
	600 kg/ha (NPK-Urea-SP 36)			720 kg/ha (NPK-Urea-SP 36)			
	HGHrL	HRHrL	HGHrL/ HRHrL (A)	HGHrT	HRHrT	HGHrT/ HRHrT (B)	A/B
L39/MR4	175.573	171.698	1.0226	182.963	179.014	1.0221	1.0005
MGOLD/G8	173.507	171.698	1.0105	174.360	179.014	0.9740	1.0375
G28/MGOLD	159.470	171.698	0.9288	177.523	179.014	0.9917	0.9366
P27	178.243	171.698	1.0381	181.210	179.014	1.0123	1.0255

Table 8. Growth characters and GYEI correlation

Parameters	GYEI	Plant Height (cm)	Corncob Notch Height (cm)	Corncob Length (cm)	Corncob Diameter (cm)	Number of Rows/ Cob	Number of Seeds/Rows
GYEI	1	0.1158	- 0.2540	0.9272	0.3017	0.8434	- 0.6987
Plant Height (cm)	0.1158	1	0.8881	0.4634	- 0.4243	- 0.4096	0.6264
Corncob Notch Height (cm)	- 0.2540	0.8881	1	0.1267	- 0.2646	- 0.6380	0.8156
Corncob Length (cm)	0.9272	0.4634	0.1267	1	0.2046	0.6171	- 0.4000
Diameter Corncob (cm)	0.3017	- 0.4243	- 0.2646	0.2046	1	0.6300	- 0.5972
Number of Rows/Cobs	0.8434	- 0.4096	- 0.6380	0.6171	0.6300	1	- 0.9644
Number of Seeds/Rows	- 0.6987	0.6264	0.8156	- 0.4000	- 0.5972	- 0.9644	1

Table 9. Growth characters and GYEI regression

Regression	Regression Equation	Significance
Plant Height and GYEI	y = 0.001049 x + 0.806433	$p > 0.05^{ns}$
Corncob Notch Height and GYEI	y = - 0.00146 x + 1.12074	$p > 0.05^{ns}$
Corncob Length and GYEI	y = 0.065958 x +-0.5232	$p > 0.05^{ns}$
Corncob Diameter and GYEI	y = 0.009231 x + 0.544126	$p > 0.05^{ns}$
Number of Rows/Cobs and GYEI	y = 0.032675 x + 0.482595	$p > 0.05^{ns}$
Number of Seeds/Rows and GYEI	y = - 0.00914 x + 1.333806	$p > 0.05^{ns}$

The yield component character is more closely related to the GYEI character than the growth character. Table 8 showed that the yield component characters closely correlated with GYEI were cob length (r = 0.93), followed by the number of rows/cobs (r = 0.84). The characters consistently positively correlated with seed/cob weight (Table 5) and positively correlated with GYEI (Table 8) were the number of rows/cobs.

The studied four lines/varieties showed that the number of rows/cobs was an alternative indicator in identifying high yielding and efficient fertilization lines/varieties. However, Table 9 showed that the regression among the number of rows/cobs with weight of seeds/cobs and the number of rows/cobs with GYEI was not significant. This, it is necessary to test other hybrid maize lines to identify lines that have very significant regression, between the number of rows/cobs and the weight of seeds/cobs and between the number of rows/cobs and GYEI.

CONCLUSION

The number of rows/cobs is an alternative variable in identifying high yielding lines/varieties and efficient fertilizing. These characters were consistently closely correlated with seed/cob weight (r = 0.94) and seed Yield Efficiency Index/GYEI (r = 0.84). Another approach that could be used to identify efficient fertilization lines/varieties was the variable percentage of yield reduction through regression equations with GYEI (y = - 0.0104 x + 1.0426).

ACKNOWLEDGEMENT

The research was financed by the Indonesian Agency for Agricultural Research and Development (IAARD) through South Sumatra Assessment Institute for Agricultural Technology (South Sumatra AIAT). The authors would like to thank Mr. Juwedi, Mr. Budiono, and Mr. Siswanto for their assistance. Thanks are also extended to the editor and reviewers for their constructive comments on this manuscript.

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