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Growth Performance and AMMI Yield Stability Analysis of Five New Maize Hybrid Populations

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***Abstract*— Multi-environment yield trials are essential in an estimation of genotype by environment (GE) interaction and identification of superior genotypes in the final selection cycles. The objective of this study was to evaluate yield stability of five hybrid maize in three locations using AMMI (Additive Main Effects and Multiplicative Interaction) method. A randomized block design with three replications was applied to the experiment at each site. The genotypes tested were UNIB CT5, UNIB CT8, UNIB CT9, UNIB CT13, and UNIB CT14. The hybrids were single-crosses from selected pairs of S6 gamma irradiated mutant parental lines. The hybrids were cultivated in three different locations with different agroclimatic. They were Air Duku village, district of Curup, Rejang Lebong (rainy season of the year of 2014); Kandang Limun village, district of Muara Bangkahulu, Bengkulu (wet season of the year of 2015) and Medan Baru village, district of Muara Bangkahulu, Bengkulu (dry season of the year of 2015). The results showed that among five newly developed hybrids tested, CT8 and CT9 were the most prospective genotype for Ultisol for a dry and wet season, respectively. Based on the postdictive success and predictive success methods, the model used (AMMI 2) was able to explain 89% interaction-influenced variation. The genotypes found stable in three locations based on AMMI analyses was UNIB CT14. Three hybrids were considered specific adaptation. They were UNIB CT9 for rainy season of Kandang Limun, UNIB CT8 for dry season of Medan Baru and UNIB CT13 for rainy season of Curup. UNIB CT5 did not adapt to any of the three environments tested.**

***Keywords*—yield; stability; maize hybrid; AMMI.**

I. Introduction

Maize (*Zea mays* L.) is one most widely grown grain crops in Bengkulu Province of Indonesia and is the second staple food crop following rice. It is rich in nutrition such as essential fatty acid, flavonoid, minerals (Ca, Mg, K, Na, P, Ca and Fe), anthocyanin, beta-carotene (provitamin A), essential amino acid, and food fiber needed by human body [1]. Due to this high nutrition contents, maize is classified as a functional food. Increasing demand for functional food is because of increasing people awareness on health, degenerative disease sufferer, and ageless population. Moreover, food technology improvement enhances scientific information on the benefit of functional food components.

High carbohydrate content makes maize suitable for a raw material of fodder as well as food and industry [2]. About 50% of fodder composition is made up from maize. The lack of maize grain will increase the price of fodder and, consequently, meat. So that maize is a strategic commodity of food security in Indonesia.

National demand for maize increases annually. The Higher amount of demand compared to the national production leads to significant amount of import every year. In the year of 2014 imported maize amounted to 3.25 million metric tons [3] and in the year of 2015 increased to the amount of 3.27 million tones [4]. In the year of 2017 maize import was predicted will be much higher.

There is a high potential to increase corn production in Indonesia through extending planting areas because dry arable land is widely available, although most of them were acidic soil such as Ultisol. Ultisols occupy approximately 45.8 million ha of the total land area in Indonesia [5]. Based on distribution and size, these soils are perhaps the next highest in land area compared to Inceptisols (the most important soils in Indonesia), a clear indication of the great potential of Ultisols for expanding agricultural operations in the country [5]. However, as Ultisols are acidic and highly leached, they exhibit several constraints such as Al-toxicity and low nutrient content for plant growth [6].

This great potential of the maize planting area has to be equalized with enough seed availability of adapted maize cultivars to acidic soil with low availability of P. Ultisol have low pH value which restricts the solubility of phosphor as it is converted to become a non-soluble form of $Al_2(PO_4)_3$.

In comparison to open pollinated or composite cultivars, the yield potential of hybrid cultivars is considerably higher.

Under intensive small-scale practices, the yield potential of OPV is lower than that of hybrid cultivars [7]. On acidic soil, the yield potential may be much lower than these levels. Evaluation on maize hybrid Pioner 21 intercropped with upland rice in Ultisol amended with 10-ton ha^{-1} manure in Indonesia showed the highest yield of 4.12-ton ha^{-1}[8].

There is a continual concern about reduced genetic diversity in elite maize germplasm and the potential effects this might have on future maize productivity under different climatic and environmental. Recently, cultivar development of many crops has been directed toward cultivars which are adaptive to a location to support environmental sustainability [9]. Multi-site trial is necessary to obtain genotypes adaptive to environment, or genotypes which are stable over a range of environmental condition [10]. Multi location test on the yield is an important plant breeding step of cultivar development before a cultivar is being released as a new superior variety because the yield is a function of genetic by environment interaction [11].

Generally, there are two factors considered in a multi-location test, i.e. genotype and location. Analysis model to identify genotype x environment (GE) interaction is a combination of analysis of variance (ANOVA) and principal component analysis (PCA). An additive model of analysis of variance explains only the main effect and rationalizes whether the GE interaction is the source of variation [12]. A high value of GE interaction describes the ability of a genotype to express most of its beneficial genes contributing high yield in certain environments. Accordingly, the GE interaction determines gene expression on a trait [13]. Employing only those two methods, however, is not satisfied to explain more deeply the interaction pattern especially for the more complex data.

Additive main effect and multiplicative interaction (AMMI) is highly effective to explain GE interaction. Mostly, AMMI analysis combines the analysis of additive variance on the principal effect of the treatment with second principal component analysis by a bilinear model on the interaction effect [12]. The suitable growing condition of genotypes can be plotted precisely in a simultaneous genotype and environment graph with biplot [13]. Multi-environment yield trials in maize are necessary for evaluation of genotype by environment (GE) interaction and identification of excellent genotypes in the final selection cycles. Thus GE biplot analysis is useful for identifying locations which optimize cultivar performance and on better utilization of constrained resources available for the testing program ([14], [15]).

The objective of this research was to evaluate GE interaction effect and to determine the stability of five new hybrids on three different environments of Bengkulu Province by AMMI analysis.

II. Material And Method

The plant materials evaluated were five new maize single-cross hybrids of the sixth inbreed generation (S6) gamma irradiated mutants [16]. Gamma irradiation was done in the National Nuclear Energy Agency of Indonesia, and inbreeding was conducted manually on acidic soil Ultisol up to the sixth generation. The hybrids were CT5, CT8, CT9, CT13, and CT14. The multi-location test was conducted in three locations with a different environmental condition in term of altitude, soil type, soil physical properties, season, and climatic properties including rainfall, relative humidity, and air temperature. During the wet season, the experiment was done in Curup, Rejang Lebong Regency (the year of 2014) and Kandang Limun, Bengkulu City (the year of 2015); and during the dry season the year of 2015, the experiment was done in Medan Baru, Bengkulu City (Table 1). In each location, the experiment was arranged in a randomized complete block design (RCBD) with three replications. The treatment was five hybrids which were placed randomly in the block so that there were 15 experimental units.

The experimental unit was a 3 m x 5 m plots consisting of 80 plants, and between plots were spaced 50 cm apart. Plant spacing was 25 cm in a row and 75 cm apart between rows. The seeds were single seeded in every planting hole applied with carbofuran insecticide at a rate of 20 kg ha-1 to protect the seed from any insect attacks. Reseeding was done at seven days after planting to replace non-germinating seed.

Fertilizer application of urea, TSP, and KCl at the rate of 150, 200, and 150 kg ha^{-1}, respectively, were done at planting time. The second application of urea was done at 30 days after planting at a rate of 150 kg ha^{-1}. The dose of urea used was an optimum level for growth and yield of maize hybrid variety for natural non-acidic soil [17].

Plant maintenance was done in conventional maize cultivation including weeding, pest and disease control, and row-piling. Weeding was done mechanically by short-handled small hoe at 3, 5 and seven weeks after seeding. Insecticide and fungicide were applied preventively every other week appropriately following the government agency recommendations. Stem and cob borer were controlled with deltamethrin insecticide at a concentration of 2 $ml.L^{-1}$. Blast and downy mildew were controlled with 2 $g.L^{-1}$ mancozeb and propinep fungicide. Row-pilling was done by lifting up the soil between plant rows and piling them to cover the bottom of the plant stem. Row-piling was done at seven weeks after planting to strengthen the plant stand.

Agronomic traits measured included plant height, stem diameter, number of grain per ear and yield. Plant heights were measured as the average height in cm from ground to the last node below the tassel. Stem diameter was measured at the second internode above the ground, in mm unit. Both were taken pre-harvest at the end of the growing season. Harvesting was carried out at full maturity stage indicated with dry, hard and shiny kernels were detected in more than 75% of the plant population. The cobs were pulled out from the plant, stripped their husks, and sun dried. The grains in each ear were loosened from their ear and counted for number of grain per ear. The dry weight of kernels per plot at 14% water content was measured with a digital balance and then was converted into unit of ton ha-1 following the formula of [18].

$$Y = \frac{1000}{HA} x \frac{100 - MC}{100 - 14} xHGW \qquad (1)$$

where Y = grain yield ($kg.ha^{-1}$)
HA = harvested area (m^2)

MC	= moisture content (%) at harvest
HGW	= harvest grain weight (kg)

Combined analysis of variance was applied to determine hybrid genotype x environment interaction with a mathematical linier model as the following equation.

$$Y_{ijk} = \mu + \alpha_i + \beta(\alpha)_{ij} + \gamma_k + (\alpha\gamma)_{ik} + \varepsilon_{ijk} \quad (2)$$

where
Y_{ijk} = the observed value
μ = general mean
α_i = effect of the i^{th} location
$\beta(\alpha)_{ij}$ = effect of the j^{th} replication in the i^{th} location
γ_k = effect of the k^{th} genotype
$(\alpha\gamma)_{ik}$ = interaction effect of the k^{th} genotype x i^{th} location
ε_{ijk} = experimental error

Mean separation was done by Duncan's multiple range test (DMRT) if there was a significant difference on the effect of genotypes. AMMI analysis was employed in determining the effect of genotype x environment interaction followed by biplot analysis to simplify the data interpretation. Biplot allows plant breeders to visualize data from multiple environments to determine stability across environments. Stability is an important trait for maize breeders to measure because elite hybrids must be able to respond and perform well across multiple environments. The mathematical model of AMMI presented by [19] was as the following equation.

$$Y_{ge} = \mu + \alpha_g + \beta_e + \sum_{n=1}^{N} \sigma_n \gamma_{gn} \delta_{en} + \rho_{ge} \quad (3)$$

where:
Y_{ge} = yield of the g^{th} at the e^{th} environment
μ = general mean
α_g = deviation of the g^{th} genotype from the general mean
βe = deviation of the e^{th} environment from the general mean
N = number of Principle Component (PC) Axis in the model
σ = singular value of the n^{th} PC axis
Y_{gn} = eigen vector of the g^{th} genotype on the n^{th} PC axis
δ_{en} = eigen vector of the e^{th} environment on the n^{th} PC axis
ρ_{ge} = residual error

III. Results And Discussion

The locations in this research were selected based on the differentiation on agro-climate for maize cultivation due to the variation in altitude, soil fertility, rain fall, temperature, and relative humidity. In term of elevation, high and low altitude was represented by the location of Curup (1100 m asl), and by the site of Medan Baru and Kandang Limun (10 m asl), respectively. Based on soil fertility, fertile soil was represented by Andosol type soil with medium pH level (5.6), and acidic and less fertile soil by Ultisol with low pH level (<5). The soil pH level most suitable for maize was in a range of 5.6 to 7.5 [1]. On the contrary, the soil pH level of Medan Baru and Kandang Limun were very low i.e. 4.3 and 5.5, respectively. Based on climatic data recorded during the research period, Curup location seemed to have rain fall intensity, air relative humidity, and average temperature most appropriate to the growth of maize plant. In contrast, an extreme inappropriate condition, which was a combination of acidic soil and low water availability, was found in Medan Baru location during dry season planting period. This situation represented an extreme marginal land in Indonesia.

A. *Combined Analysis of Variance.*

The combined analysis of variance on plant height showed that there were significant differences among location, replication within locations, and genotype. However, for stem diameter, a significant difference was only observed on the effect of location. Neither genotype nor genotype x location interaction did significantly contribute to the total variance (Table 2). The effect of location or genotype was highly significant ($P<0.01$) on number of grain per ear. The interaction of genotype x location was not significant, though. The response pattern of genotypes was similar in every location.

Analysis of variance on the grain yield showed that the location and GE interaction were significant difference at $P<0.05$, whereas genotype was significant difference at $P < 0.01$ (Table 3). The significant difference of location indicated that the chosen locations diverged in their characteristic. Variation of location was mainly determined by altitude, soil type and season, which created variation in micro-climate influencing plant growth and yield of maize.

TABLE I
Characteristics of Location in the Yield Evaluation of Five New Maize Hybrids

Characteristics	**Location**		
	Curup, Rejang Lebong	**Medan Baru, Bengkulu City**	**Kandang Limun, Bengkulu City**
Altitude (m asl)	1100	15	20
Soil type	Andosol	Ultisol	Ultisol
Soil characteristics*			
pH (H20)	5.60 (medium)	4.30 (very acidic)	4.50 (very acidic)
N total (%)	0.30 (low)	0.20 (low)	0.11 (low)
P2O5 (ppm)	6.50 (low)	1.90 (very low)	6.40 (low)
$K_{exchangable}$ $(me(100g)^{-1})$	0.30 (low)	0.77 (high)	0.14 (low)
$Al_{exchangable}$$(me(100g)^{-1})$	-	1.03 (very high)	0.97 (high)
Season	rainy	dry	rainy
Climatic data**			
Rain fall (mm $month^{-1}$)	325.50	43.96	158.56
Humidity	86.30	83.33	84.53
Average temperature	23.60	27.10	26.87

*= Analyzed in the Soil Laboratory of the University of Bengkulu; **= mean data during the period of research

TABLE II

MEAN SQUARE VALUE OF COMBINED ANALYSIS OF VARIANCE ON THE NUMBER OF GRAIN PER EARS AND YIELD OF FIVE MAIZE HYBRID GENOTYPES AT THREE DIFFERENT LOCATIONS

Source of variation	df	Plant Height	Stem Diameter
Location	2	4572.77 **	1360.66 **
Rep (Location)	6	607.24 **	1.38 ns
Genotype	4	1077.72 **	1.75 ns
Genotype x Loc	8	546.49 **	0.89 ns
Error	24	128.66	0.56

df: degree of freedom, ** : significant difference at P<0.01, * : significant difference at P<0.05, ns: not significant

TABLE III

MEAN SQUARE VALUE OF COMBINED ANALYSIS OF VARIANCE ON THE NUMBER OF GRAIN PER EARS AND YIELD OF FIVE MAIZE HYBRID GENOTYPES AT THREE DIFFERENT LOCATIONS

Source of variation	df	Number of Grain per Ear	Yield
Location	2	189815.24 **	13.80 *
Block (Loc.)	6	3403.77 ns	1.68 ns
Genotype	4	16174.54 **	3.47 **
Genotype x Loc.	8	1893.02 ns	1.97 *
Error	24	1696.95	0.80

df: degree of freedom, ** : significant difference at P<0.01, * : significant difference at P<0.05, ns: not significant difference

A significant difference was observed on the effect of genotype by location interaction on all variables indicated that location contributed an important role on the performance of genotypes. One genotype might perform well in a more suitable location and poor in a less-appropriate environment. Genotype x environment interaction was able to influence plant expression [20]. The ranking performance of genotypes in one location might change in other location. Concerning the mean square (MS) value, location was higher than that of GE interaction which indicated that the effect of the environment was more predominantly compared to that of genetic factors.

B. Growth and Yield Performance

The vegetative growth of the five hybrids evaluated was very good. At location Curup, the height of CT5 (163.93 cm) was higher than that of other hybrids. Hybrid CT8 was slightly lower but not significantly different from CT5 (Table 3). The other hybrids, CT9, CT13, and CT14, were significantly lower than CT5. High plant height which was not followed by large stem diameter might increase logging. The stem diameter data showed that the five hybrids were not significantly different. Thus, in terms of plant strength, CT5 was a poor plant growth in the location of Curup. When it was associated with seed yield per ear, CT5 also had the lowest number of seeds. In high altitude, maize crops tended to have low seed yield per ear. The best hybrids at these sites were CT9, CT13, and CT14.

The vegetative growth of CT8 hybrid was superior from that of other hybrids at the Medan Baru. With high soil acidity (pH 4.5) and adequate rainfall (156.56 mm month-1), the hybrid grew well. With regard to stem diameter and number of seed per ear, however, all hybrids performed similarly, except CT5 which showed the lowest value.

In Kandang Limun, there was a high variation in plant vegetative growth. In stress condition, which was low pH and rainfall, CT8 was significantly better in growth indicated by high plant height and stem diameter. Then the following rank was CT9, CT13, and CT14. The least one was CT5, which had the lowest plant height and stem diameter. However, the number of seeds per ear of the five genotypes was not significantly different.

TABLE IV

GROWTH AND NUMBER OF GRAIN PER EARS OF FIVE MAIZE HYBRID GENOTYPES AT THREE DIFFERENT LOCATIONS

Genotipe	Plant Height (cm)	Stem Diameter (mm)	Number of Grain per Ear
Curup			
CT5	163.93 a	2.45 a	406.0 b
CT8	150.53 ab	2.50 a	476.3 ab
CT9	132.73 b	2.54 a	554.4 a
CT13	137.20 b	2.31 a	528.5 a
CT14	129.07 b	2.42 a	503.6 a
Average ± SE	142.69±2.88	2.44±0.02	493.77±11.39
Medan Baru			
CT5	112.60 b	17.49 b	194.2 b
CT8	146.67 a	19.36 ab	302.2 a
CT9	120.00 b	20.12 a	301.1 a
CT13	128.40 ab	18.00 ab	303.8 a
CT14	118.53 b	18.50 ab	266.4 a
Average ± SE	125.24±2.65	18.69±0.21	273.53±9.40
Kandang Limun			
CT5	141.40 c	1.62 c	295.6 a
CT8	189.20 a	2.29 a	387.7 a
CT9	154.60 bc	2.06 b	363.9 a
CT13	149.80 bc	1.87 b	338.2 a
CT14	165.80 b	1.93 b	333.7 a
Average ± SE	160.16±3.70	1.95±0.05	343.83±6.92

Means within the same column in the same location followed by the same letter are not significantly different according to DMRT ($p \leq 0.05$)

The mean kernel yield was greatly varied among locations. Statistical analysis figured out that there was not any hybrid tested showed consistently higher yield than other hybrids. In Curup location, with the soil type and climatic condition were more suitable for maize, hybrid CT8, CT9, CT13, and CT14 showed a similar level of yield (Fig. 1). The highest yield was observed on hybrid CT13 (5.39 ton. ha^{-1}). Whereas, CT5 was significantly lower than others. Those yield data was in harmony with the data of vegetative growth and yield component of the hybrids.

In the location of Medan Baru with the less soil fertility and drier climatic condition, CT8 significantly produced higher yield (6.024 ton. ha^{-1}) compared to CT13, CT14, CT9, and CT5 did (Fig. 2). Yield evaluation of maize hybrids on Ultisol in Nigeria with application of 18 ton ha^{-1} manure showed the highest grain yield was only 2.3 ton ha^{-1} [21] and 2.89 ton ha^{-1} [22]. It seems that CT8 will be one of the promising new maize hybrid suitable for acidic and drought stress soil. On the contrary, hybrid CT5 is the most sensitive one for stress environment, indicated by the lowest yield.

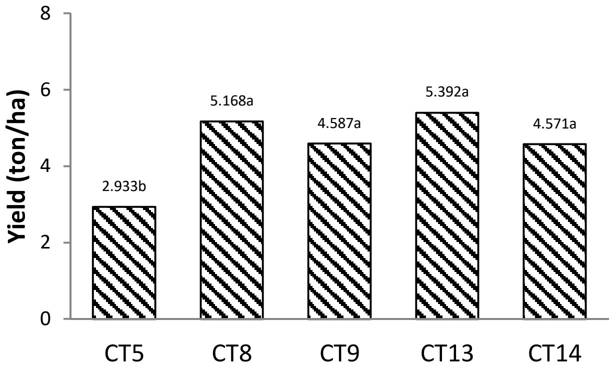

Fig. 1. Diagram of the yield of five maize hybrid genotypes grown in location of Curup, Rejang Lebong, Bengkulu, Indonesia

In Kandang Limun location, the highest yield was achieved by hybrid CT9 (7.6 ton. ha^{-1}). At this location, climatic conditions were quite supportive for the growth of maize. Average rainfall per month was 158.56 mm $month^{-1}$. Although on nutrient-poor soil (low N, P and K content and high acidity), with sufficient water supply, the hybrid CT 9 was capable of producing up to 7,6 $ton.ha^{-1}$ (Figure 3).

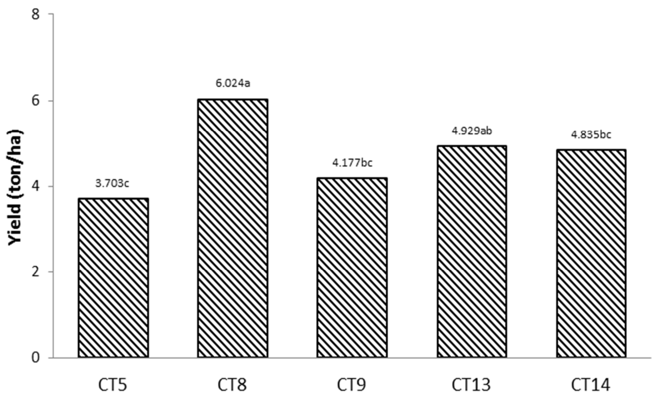

Fig. 2 Diagram of the yield of five maize hybrid genotypes grown in location of Medan Baru, Bengkulu City, Indonesia

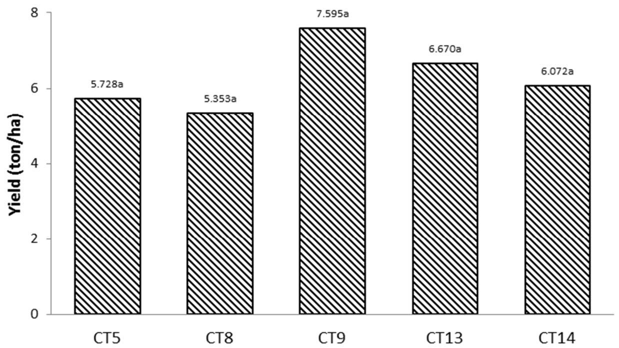

Fig. 3 Diagram of the yield of five maize hybrid genotypes grown in location of Kandang Limun, Bengkulu City, Indonesia

The yield of hybrid CT8 was slightly higher in a stressed environment (Medan Baru, Bengkulu City) than in more favorable conditions (Curup, Rejang Lebong Regency). Hybrid CT8 was likely superior in acid conditions and dry climates, while CT9 was acid-tolerant but it required sufficient watering. In the optimum population following [15], the potential production of CT9 could reach 10.2 ton. ha^{-1}. Hybrid CT 9 is the most prospective hybrid genotype for Ultisol.

Those result revealed the strength of environmental effect on genotype tested so that there was not any consistent performance of genotypes at different locations. Genotypic response to environmental conditions determined the consistency of yield superiority of hybrids in a different location [8][23].

C. Yield Stability

Analysis of variance is an additive model which merely describes the effectiveness of the main effect. This model was also capable of explaining the effect of GE interaction; however, it cannot account for the pattern of the interaction [12]. AMMI method equipped with the biplot can simplify the relationship among genotypes, environments, and genotype by environment interaction [10]. The results of bilinear separation on the effect of genotype x environment interaction matrices obtained the singular value of 2.1705, 0.7373 and 0.000. Those unique values led to a conclusion that appropriate components to be considered in AMMI model were IPCA 1 and IPCA 2 (Table 5). The contribution of variance which could be explained by IPCAs was 89.66 and 10.34%, respectively. It could be noticed that the first component took dominant part to explain the variation of interaction. It also clarified that the presumption of high genotype x environment interaction effect on yield was true.

TABLE V
AMMI ANALYSIS OF VARIANCE ON THE YIELD OF FIVE MAIZE HYBRIDS ON THREE DIFFERENT LOCATIONS

Source of Variation	df	SS	MS	F_{cal}	P
Location	2	27.591	13.795	8.230	0.019 *
Block(Location)	6	10.063	1.677	2.110	0.090 ns
Genotype	4	13.872	3.468	4.350	0.009 **
Genotype x Location	8	15.764	1.971	2.470	0.041 *
IPCA1	5	14.133	2.827	3.550	0.015 *
IPCA2	3	1.631	0.544	0.680	0.571 ns
Error	24	19.115	0.796		
Total	44	86.403			

There were two methods to determine the number of principal component axises; they were postdictive success and predictive success methods [19]. The former method deals with the ability of a reduced model to predict data which is used to construct a model. On the other hand, the latter method correlates with the capacity of a model to forecast other non-constructing model data or validation data. The number of best PCs was the one which had the least value of Root Mean Square Predictive Different (RMSPD) on validating data.

Based on the postdictive success method on AMMI analysis of variance, genotype x environment interaction component which had significant difference was the first PC (IPCA 1) with the F value of 3.35 and the probability of 0.015 (Table 5). This result indicated that maize yield was influenced by location, genotype, and their interaction. According to the predictive success method, AMMI 2 had the least RMSPD value, which was 5.645, whereas AMMI 1 was 6.025. Hence, AMMI 2 method was the better way to determine the number of PCs in AMMI model.

AMMI 2 model was able to explain variance interaction of 84.71%, which meant that the prediction of genotype x environment interaction was high. AMMI model was able to increase the accuracy of the prediction when only a few of the AMMI component which was significant [24]. In this study, the variance which was not capable being explained by the model was only 15.29%.

The interpretation of results obtained from an AMMI analysis is performed with a biplot to relates genotypic means to the first or some of the principal interaction components [25]. In this study, Bi plot was a visualization tool of AMMI analysis to determine hybrid(s) stable over location trials, or the one(s) specific for certain location. Stable genotype is the genotype situated close to the main axis, whereas the genotype suitable for the specific location if it is located further from the main axis but close to the certain environmental axis [26]. Based on the biplot graph, the most stable hybrid genotype over three locations was UNIB CT14.

From biplot AMMI, it was noticed that certain genotypes in one environment have a higher yield than in other environments i.e. there is a specific interaction between genotypes and environments. Three other hybrids in this study were likely specific locations, i.e. UNIB CT9, UNIB CT8 and UNIB CT13 were a particular location for Curup, Kandang Limun, and Medan Baru, respectively (Fig 4). UNIB CT9 exhibited high yield (7.595 ton ha^{-1}). UNIB CT5 was not suitable for all location trials as it was far from the center and neither was it close to any location axis (Fig. 4).

IV. Conclusion

Based on growth performance, hybrid of UNIB CT8 and UNIB CT9 were most suitable for ultisol type dry land of Bengkulu. Maize hybrid UNIB CT14 exhibited good adaptation and stable performance in three different location of Bengkulu. Maize hybrid UNIB CT9, UNIB CT8 and UNIB CT13 demonstrated to adapt to location trials of Kandang Limun, Medan Baru, and Curup, respectively. Maize hybrid UNIB CT5 was not suitable to any of the three location trials.

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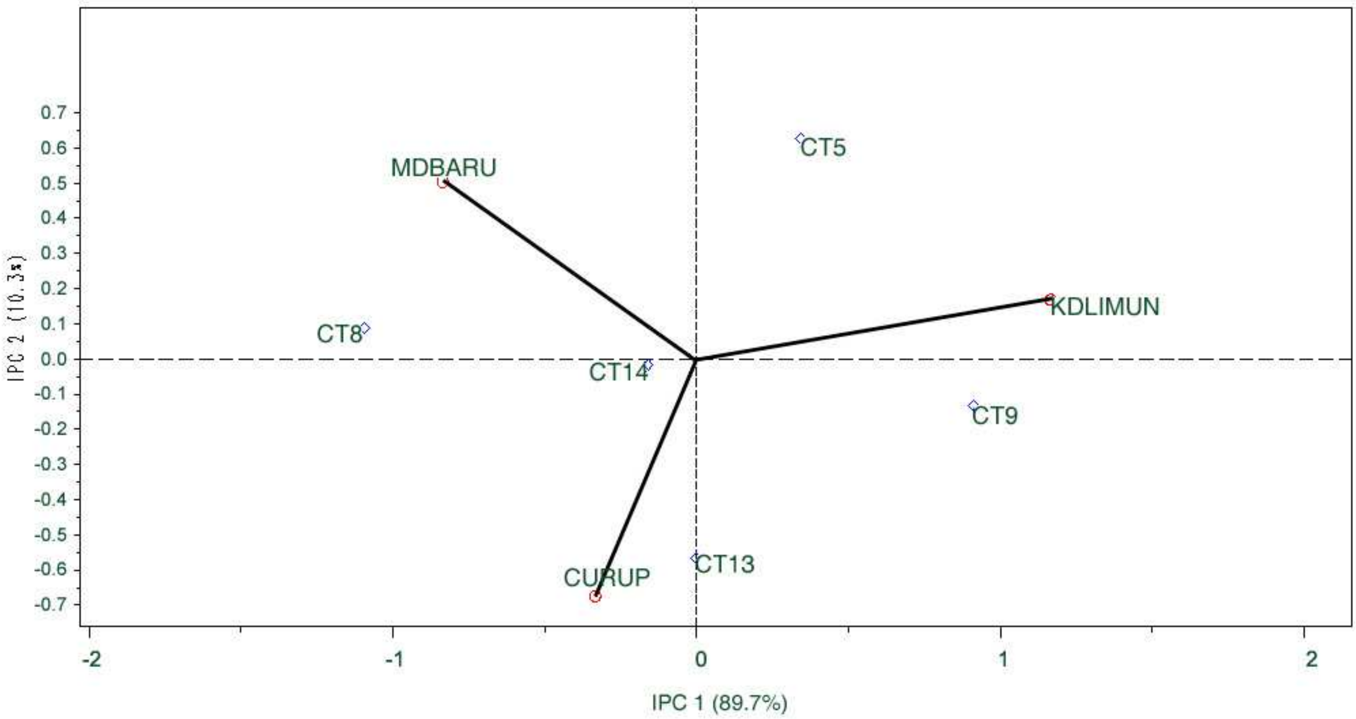

Fig. 4 Biplot diagram of genotype x environment interaction of the AMMI model on yield data of five maize hybrids in three different location of Bengkulu Province (model suitability: 84.71%)

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