Gunung Djati Conference Series, Volume 66 (2026)
Proceedings of the International Conference on Perennial Crops
ISSN : 2774-6585
Website : https://conferences.uinsgd.ac.id/

EVALUATION OF YIELD PERFORMANCE, ADAPTABILITY, AND DOWNY MILDEW RESISTANCE OF HYBRID MAIZE CANDIDATE BAY233 ACROSS DIVERSE ENVIRONMENT IN INDONESIA

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ABSTRACT

The development of high-yielding and well-adapted maize hybrids is essential for ensuring the sustainability of maize production in Indonesia. This study aimed to evaluate yield performance, adaptability, stability and downy mildew resistance of the hybrid candidate BAY233 across different agroecological environments. Multilocation trials were conducted during 2023-2024 planting season at ten testing locations representing major maize-production regions in Indonesia. The experiment was arranged in a randomized complete block design with six replications. BAY233 evaluated alongside with BAY234 and two commercial check varieties, BISI959 and NK7328. Yield performance was analyzed using analysis of variance (ANOVA), while genotype x environment (GxE) interaction and stability were assessed using the Additive Main Effects and Multiplicative Interaction (AMMI) model. Resistance to downy mildew was evaluated through artificial inoculation using *Peronosclerospora philippinensis* and *P. maydis*. BAY233 produced grain yields ranging from 8.43 to 12.40 t ha^{-1} across test locations. Although its stability was slightly lower than that of BAY234 but still categorized as promising hybrid due to its performance. BAY233 demonstrated superior yield performance and broad adaptability. Furthermore, BAY233 exhibited strong resistance to downy mildew, as indicated by its low incidence under artificial inoculation test. These findings suggest that BAY233 is a promising hybrid candidate for commercial release and cultivation in Indonesia owning to its high yield potential, broad adaptability, and disease resistance.

Key words: Adaptability, AMMI, G×E interaction, Hybrid maize, Multilocation trial

INTRODUCTION

Maize (Zea mays L.) is one of the most important food crops worldwide and is considered as a strategic food crops commodity in Indonesia. This crop is also extensively utilized by several sectors such as feed, food processing, and bioindustry. The demand for maize is increased by time and continuously stimulated the demand for higher maize productivity and production stability. Food and Agriculture Organization (FAO) in 2024 reported that maize remains as the most widely cultivated food crops worldwide, highlighted its critical contribution to global food and feed security.

To address this challenge, Scientists, plant breeder along together with government agricultural institution respond this phenomenon using effective approach by developing new superior hybrid variety for improving maize characteristic. The improvement focuses on possessing high yield potential, wide adaptation, and resistance to major diseases. Hybrid breeding program categorized as the most effective approach for increasing yield productivity in maize. In modern technology, the hybrid breeding method integrates conventional selection method with advanced phenotyping and genomic tools on improving the development of superior hybrid (Xu *et al*., 2023). However, the performance of hybrid maize is also influenced by its environmental variation. Genotype × environment (G×E) interaction frequently affected inconsistent varietal performance across locations, making multilocation evaluation essential before commercial release. Some study reported that environmental aspect frequently gave impact on a larger proportion of yield variation (Yan and Frégeau-Reid, 2018; Oliveira *et al*., 2024).

BAY233 is a new hybrid candidate developed in Thailand though intensive breeding and selection program. This program focuses on making new generation of maize with high grain yield, good lodging resistance, uniformity, and resistance to downy mildew. BAY233 is a single cross breeding hybrid developed from parental crops D7023Z and G2484Z. Preliminary evaluations on this variety indicated promising agronomic performance and good adaptation ability under various agroecological conditions.

Therefore, this study aimed to evaluate the yield performance, adaptability, and downy mildew resistance of BAY233 across various agroecological conditions in Indonesia.

MATERIALS AND METHODS

This study conducted at ten different locations in Indonesia during the 2023–2024 planting season. Each planting location represent lowland to medium altitude environments ranging from 29–185 m above sea level (Table 1) and represent various agroecological condition, soil type, and climate condition according to Oldeman classification.

The genetic material in this study used two hybrids maize BAY233 and BAY234, and commercial check material as comparison consist of NK7328 and BISI 959.

Tabel 1. Description of Test Locations for the 2023-2024 Planting Season

Trial Location	Above sea level (m)	Soil Type	Climate Type	Planting Date	Harvesting Date
Tawangharjo, Grobogan, Central Java	50	Alluvial Rice Field	C3	22-Nov-23	12-Mar-24
Banyudono, Boyolali, Central Java	185	Latosol Rice Field	C1	26-Dec-23	18-Apr-24
Tambakboyo, Tuban, East Java	41	Alluvial Rice Field	C1	27-Nov-23	13-Mar-24
Sambit, Ponorogo,	128	Lithosol Rice	C1	04-Dec-23	20-Mar-24

East Java		Field			
Patampanua, Pinrang, South Sulawesi	36	Regosol Rice Field	B1	22-Dec-23	07-Apr-24
Tamalatea, Jeneponto, South Sulawesi	119	Regosol Dryland	C2	04-Dec-23	20-Mar-24
Pammana, Wajo, South Sulawesi	57	Grumusol Dryland	B2	01-Dec-23	16-Mar-24
Kempo, Dompu, West Nusa Tenggara (NTB)	29	Lithosol Dryland	D1	02-Dec-23	23-Mar-24
Margosari, Jatiagung, South Lampung	39	Podzolic Rice Field	C3	30-Nov-23	14-Mar-24
Purwodadi Mekar, Batanghari, East Lampung	31	Podzolic Rice Field	C3	03-Dec-23	22-Mar-24

The study used a Randomized Complete Block Design (RCBD) with six replications (Figure 1) on each testing location. Each genetic material planted in four row using 70 cm planting spacing between rows and 20 cm planting spacing between within rows. Seeds are sown per hill and thinning out at 10-15 days after planting (DAP) subsequently to achieve targeted population.

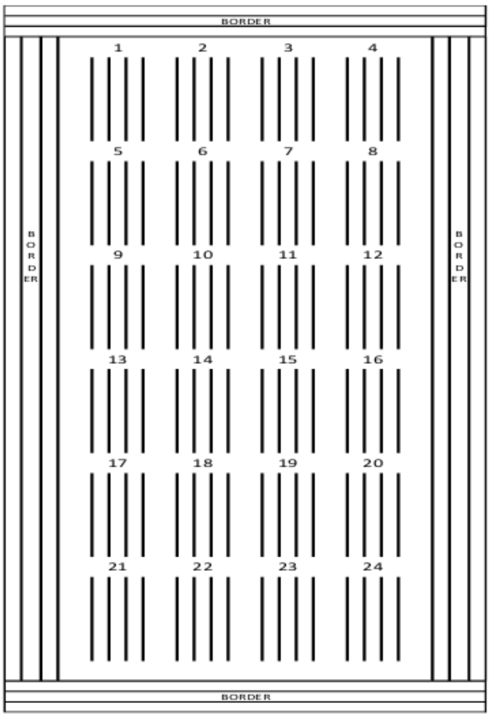

Figure 1. Experiment Layout

Standard agronomic practices applied in all locations in the same treatment. Replanting conducted on 10 DAP using prepared seedling. Weed control and hilling up conducted based on the environmental condition. Fertilizer application applied based on the standard recommendation. Basal fertilize, consist of 100 kg ha^{-1} urea and 300 kg ha^{-1} NPK, applied on the lack soil fertility information on 7-10 DAP. The second fertilization applied on 30-35 DAP using 250 kg ha^{-1} urea and 100 kg ha^{-1} NPK. Integrated pest management system and monitoring conducted throughout the growing season.

Harvesting conducted when crops reach their physiologically mature stage, indicated by approximately 90% husk discoloration and black layer formation on the kernel base. Harvest and post-harvest handled carefully using standard SOP to prevent contamination among genotypes.

Observation conducted from vegetative to harvesting period based on The Indonesian Technical guidelines for Maize Adaptation Testing. The parameter observed were crop yield and variety stability. Observation measure on sample plan on each treatment in testing location.

Crop resistance to major diseases such as downy mildew evaluated under artificial inoculation condition. Downy mildew caused by *P. maydis* evaluated in Kediri, East Java, whereas resistance to *P. philipinensis* was evaluated in Maros, South Sulawesi. The experiments designed in RCBD with six replications. BAY233 and BAY234 were tested alongside commercial checks hybrid and susceptible variety (Anoman). The susceptible variety also planted three weeks before as spreader rows around the testing area.

Downey mildew incidence observed at 14, 21, 28, 35, and 42 DAP and then calculated as the percentage of infected plants across the population. The severity of leaf blight and rust disease observed at 45, 60, and 75 DAP using 0-5 severity scale modified from Sharma (1983), where 0 indicated no symptoms and 5 indicated severe infection affecting most plant tissues. Disease intensity was subsequently calculated according to standard disease severity formulas.

Data analyzed using analysis of variance (ANOVA) and followed by LSD 5%. The AMMI analysis and GGE biplot approach were conducted is there were significancy for stability analysis. AMMI analysis conducted using CropStat developed by International Rice Research Institute (IRRI).

RESULTS AND DISCUSSION

This study revealed significant differences in both individual and environmental factors among the tested varieties regarding yield parameters. These differences were influenced by genetics as well as the genotype-by-environment (GxE) interaction. Specifically, BAY233 produced a mean yield ranging from 8.43 to 12.40 t ha^{-1} across all trial locations. Meanwhile, BISI959 and NK7328 produced yields ranging from 7.14 to 10.68 t ha^{-1} and 7.49 to 11.25 t ha^{-1}, respectively. BAY233 achieved a higher yield compared to the commercial check varieties in Ponorogo, Wajo, Dompu, Grobogan, and Boyolali. Additionally, BAY233 yielded higher than BISI959 in Tuban and higher than NK7328 in Pinrang. However, the yield of BAY233 was relatively similar to the commercial check varieties in Lampung Timur and Jeneponto (Table 2).

Tabel 2. Analysis of variance across testing location variety hybrids

Genotype	Yield on 15% Moisture Content Across Testing Location										
	LAMSE	LAMTI	PONOR	TUBAN	JENTO	PINRAN	WAJO	NTB	GROBO	BYLALI	AVERAGE
BAY233	12.40ab	9.52	10.95ab	10.06a	8.43	8.76b	9.57ab	8.91ab	9.41ab	10.36b	9.84ab
BAY234	11.12	10.54	6.99	7.66	8.80	8.81	10.34	8.85	8.23	10.72	9.21
BISI959	10.68	10.12	8.76	7.45	8.48	8.32	8.12	7.31	7.14	10.34	8.67
NK7328	11.25	9.56	8.89	9.37	7.89	7.84	7.69	7.54	7.49	8.03	8.55
Mean	11.36	9.94	8.90	8.64	8.40	8.43	8.93	8.15	8.07	9.86	9.07
SE	0.27	0.29	0.43	0.32	0.40	0.26	0.31	0.30	0.19	0.34	0.27
LSD(5%)	0.81	0.88	1.30	0.96	1.21	0.80	0.93	0.89	0.59	1.01	0.79
CV	5.80	7.20	11.90	9.10	11.70	7.70	8.40	8.90	5.90	8.30	8.60

The yield performance of BAY233 across the testing location indicates that this hybrid categorized as promising hybrid with good adaptation ability and high yield. The significant difference among the genotypes in this study demonstrated the importance of genetic factors in determining crop productivity in maize. Sujiprihati *et al*. (2006) reported that yield performance is highly influenced by both genotype and environmental conditions. The superior hybrids are characterized by their ability to maintain high productivity across different environmental conditions. The consistent superiority of BAY233 in several testing locations, including South Lampung, Ponorogo, Wajo, Dompu, Grobogan, and Boyolali.

Further combined analysis of variance indicated that genotype, environment, and the genotype-by-environment (GxE) interaction significantly affected yield. The genotypic mean square was four times higher than the GxE interaction mean square, indicating that genetic factors contributed more to yield variation than the GxE interaction.

Tabel 2. Combined ANOVA for grain yield traits of 4 maize hybrids across 10 locations

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Prob F
Location	9	229.451	25.4946**	22.78	0.000
L/R	50	55.96	1.1192		
Genotype	3	61.852	20.6172*	4.59	0.010
GxE	27	121.164	4.48755**	7.42	0.000
Error	150	90.731	0.6049		
Total	239	559.158			

The interaction between genotype x environment that has been observed in the combination analysis resulted that genotype performance influence by the testing location. The similar finding reported by Mut *et al*.(2010) that GxE results from differential genotype responses to environmental variation. Baye *et al*. (2011) also reported that this interaction may affected genotype rankings among the location and complicate the identification of superior variety. However, the larger contribution of genotype effects compared to G×E interaction effects in the present study suggests that genetic factors gave higher effect than environmental interactions in determining grain yield. According to Asad *et al*. (2009), when crossover interactions occurred, specific genotypes may be selected for particular environments. Nevertheless, the overall performance of BAY233 across most testing locations indicates a relatively broad adaptation pattern.

The level of stability is defined as the yield variance of a genotype across multiple environments. A genotype with lower variance across environments is considered to be more stable. The results of the stability analysis using the AMMI model are presented in Table 3

Tabel 3. Coefficient regression for stability test across trial location

Genotype	Min-Max	AVG	bi	SE	MS-TXL	MS-REG	MS-DEV	R**2(%)
BAY233	8.43-12.40	9.84	0.905	0.246	0.52	0.09	0.58	2
BAY234	6.99-11.12	9.21	0.988	0.331	0.93	0	1.04	0
BISI959	7.14-10.68	8.67	1.14	0.186	0.32	0.19	0.33	7
NK7328	7.49-11.25	8.55	0.966	0.236	0.47	0.01	0.53	0
AVG		9.07						

Stability analysis based on the slope coefficient regression (bi) and deviation from regression indicated that BAY234 possessed better stability than BAY233. Meanwhile, NK7328 was more stable than BISI959. The AMMI biplot showed that BAY233 and NK7328 were positioned in the first quadrant, whereas BISI959 was in the fourth quadrant. The grouping of these genotypes indicates that genotypes within the same quadrant are more closely related than to those in other quadrants. The AMMI biplot also reveals that the Lampung Selatan (E1) environment exhibited the lowest variance, as indicated by its short environmental vector. Conversely, the Ponorogo and Wajo (E3 and E7) environments exhibited the highest variance, as indicated by their long environmental vectors.

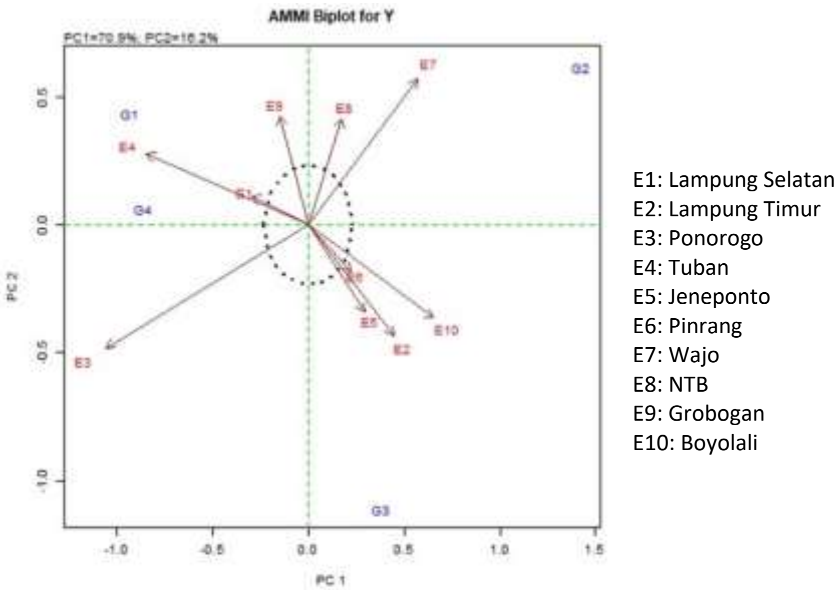

Figure 2. AMMI Biplot on yield from tested hybrids

Farshadfar *et al*. (2012) stated that stability analysis are most useful when it is interpreted together with crop productivity data. In this study, BAY233 consistently produced higher yields across testing locations but had lower stability level compared to BAY234. Therefore, BAY233 represents as crop with balanced productivity and adaptability, which is commonly preferred in hybrid breeding programs of maize.

The resistant hybrid to downy mildew is becoming a critical factor for sustainable maize production in tropical regions. The resistance evaluation for downy mildew which was caused by *P. philippinensis* resulted that BAY233 had high resistant reaction during early growing stage. The disease incidence data resulted below 3% to 28 DAP and reached 7.76% at 42DAP. This result categorized BAY233 as resistance genotype to downy mildew. Meanwhile, the disease incidence in BISI959 and NK7328 is 31.06% and 40.29% respectively at 42DAP. On the other hand, genotype still considered can be passed in hybrid evaluation, if the downy mildew resistance is not more than 40% under inoculation growing condition. P. maydis in East Java, disease incidence was considerably higher infection level around 17.88% at 28DAP and 22.56% at 42DAP. BAY233 remained categorized as resistant genotype based on the result. Meanwhile NK7328 and control genotype categorized as susceptible varieties because the incidence at 42DAP 29.62% for BISI959 and 72.63% for NK7328.

The low incidence of this disease that has been observed in BAY233 against both *P. philippinensis* and *P. maydis* indicated the presence of resistance mechanism in the genotype. Agrios (2004) explained that disease development influence by the host genetic, plant morphology, and biochemical characteristic that affected pathogen infection and colonization. The disease reactions observed between South Sulawesi and East Java indicate differences in pathogen virulence and environmental conditions that influence disease response.

Resistance to downy mildew depends on genetic variability, phenotypic traits, and the genotype and environment interaction (Azrai *et al*., 2006). The severity of downy mildew symptoms is determined by the level and timing of pathogen infection; if the pathogen reaches the leaf whorl, the infection becomes systemic, whereas less severe infections do not reach leaf whorl only cause localized symptoms (Budiarti *et al*., 2012). The strong resistance of BAY233 to downy mildew indicates the presence of resistance genes within its genome. Previous studies by Azrai *et al*. (2005), Latifani *et al*. (2014), and Muis *et al*. (2019) demonstrated that resistance to downy mildew may be governed by both major and minor resistance genes. Pakki (2017) further reported that differences in disease incidence among maize genotypes are associated with pathogen virulence and host defense responses. Therefore, the combination of high grain yield, broad adaptation, and resistance to major downy mildew pathogens qualifies BAY233 as a promising hybrid candidate for commercial release and cultivation in Indonesia.

CONCLUSION

1. BAY233 showed high yield performance on different agroecological environment in Indonesia, producing yield 8.43 to 12.40 t ha^{-1}, higher that the commercial check varieties

in the most testing location. The analysis of variance combination resulted significant effect of genotype, environment, and GxE interaction on yield parameter.
2. The AMMI analysis resulted that BAY233 possessed broad adaptation and good stability level across the environment. In addition, BAY233 also has good resistance to downy mildew disease indicated by lower disease incidence compared to the commercial check varieties.
3. The combination of high yield performance, wide adaptability, and resistance to downy mildew disease indicates that BAY233 is the promising hybrid for commercial release and large-scale cultivation in Indonesia.

ACKNOWLEDGEMENT

This work was supported by the Cooperative Research Program for Agriculture Science of Universitas Hasanuddin and PT Bayer Indonesia.

REFERENCES

Agrios, G.N. (2005). Plant Pathology (5th ed.). Elsevier Academic Press, Burlington, MA, USA.

Azrai, M., Aswidinnoor, H., Koswara, J., & Surahman, M. (2005). Pendugaan model genetik dan heritabilitas karakter ketahanan terhadap penyakit bulai pada jagung. Zuriat, 16(2).

Baye, T.M., Becker, H.C., & Von Witzke-Ehbrecht, S. (2011). Genotype × environment interactions and yield stability in maize. African Journal of Agricultural Research, 6(7), 1605–1611.

Budiarti, S.G., Muis, A., & Pabendon, M.B. (2012). Development and symptom expression of downy mildew disease in maize under different infection stages. Jurnal Penelitian Pertanian Tanaman Pangan, 31(2), 95–102.

FAO. 2024. FAOSTAT Statistical Database. Food and Agriculture Organization of the United Nations. Rome, Italy.

Farshadfar, E., Poursiahbidi, M. M., & Jasemi, M. (2012). Evaluation of phenotypic stability in bread wheat genotypes using GGE-biplot. International Journal of Agriculture and Crop Sciences, 4, 904–910.

Latifani, N., Azrai, M., & Muis, A. (2014). Evaluation of resistance mechanisms against downy mildew in tropical maize germplasm. Jurnal Penelitian Pertanian Tanaman Pangan, 33(1), 1–10.

Muis, A., Pabendon, M. B., Nonci, N., & Waskito, W. P. S. (2012, November 29–30). Keragaman genetik patogen penyebab bulai berbasis marka SSR. In Prosiding Seminar Nasional Insentif Riset SINas: Membangun Sinergi Riset Nasional untuk Kemandirian Teknologi. Kementerian Riset dan Teknologi, Bandung, Indonesia.

Mut, Z., Aydin, N., Bayramoglu, H.O., & Ozcan, H. (2010). Stability of some bread wheat genotypes for grain yield. Journal of Environmental Biology, 31(4), 489–495.

Oliveira IJ, Rocha JRASC, Nascimento M, *et al*. 2024. Genotype × Environment Interaction and Stability Analysis in Tropical Maize Hybrids. Euphytica 220: 1–15.

Pakki, S. (2017). Host resistance and pathogen virulence interaction in maize downy mildew disease. Jurnal Fitopatologi Indonesia, 13(4), 123–130.

Sujiprihati, S., Syukur, M., & Yunianti, R. (2006). Analisis stabilitas hasil tujuh populasi jagung manis menggunakan metode additive main effect multiplicative interaction (AMMI). Buletin Agronomi, 34, 93–97.

Yan W, Frégeau-Reid J. 2018. Genotype by Yield*Trait (GYT) Biplot: A Novel Approach for Genotype Selection Based on Multiple Traits. Scientific Reports 8: 8242.

Xu Y, Li P, Zou C, *et al*. 2023. Enhancing Genetic Gain in Maize Breeding Through Modern Genomic Approaches. Nature Reviews Genetics 24: 389–405.