Research Article

Stability Analysis of Peko Production in Some Genotypes of Indonesian Tea Using AMMI

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Abstract.
White tea is made from peko shoots, which is beneficial for human health as an antivirus including avian influenza, antidiabetic, anticancer, antimicrobial, and reduces oxidative stress. White tea production is still low due to the lack of peko shoot production as its raw material. This study aims to evaluate the stability of peko production of 9 Indonesian tea genotypes in producing peko shoots. Nine tea genotypes were observed at six different times. The research was conducted in a randomized block design with four replications. The time is treated as a location factor in the AMMI model, and can be assumed to be independent of each other. The results of the study showed that the main effect of time was significant for KUI1 and KUI2 tea genotypes. In the biplot it appears that GMB 3, GMB 4, Tambi 1, and Kiara 8 are stable genotypes. GMB 3 and Tambi 1 have higher stability, respectively with an average percentage of peko shoots over banji shoots of 38% and 39%. The stable genotypes could be recommended for further development.

Keywords: white tea, AMMI, randomized block design

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1. Introduction

White tea is one of the types of tea consumed in Indonesia. Compared to other types of tea, white tea undergoes the simplest processing procedures, namely withering and drying process for a long time without a fermentation process [1,2]. White tea is not only a refreshing drink but has many benefits for human health . Apart from being an antidote to the bird flu virus (H5N1) [3], white tea is also good for the heart (cardioprotective), nerves (neuroprotective), anti-diabetic, anti-cancer and anti-microbial [4] and reduces oxidative stress [5].

Tea plants produce active shoots called peko shoots. Peko shoots which contain high antioxidants are used as raw material for processing white tea. The amount of white tea production is still small due to the lack of peko shoot production. Apart from being influenced by its genotype, peko shoot production is greatly influenced by the plant's adaptability to environmental conditions. Information on the stability of a genotype is very important for breeders in identifying and selecting genotypes that perform well in given environmental conditions. In an effort to produce a superior genotype, it is necessary to test various tea genotypes. The genotype is said to be superior based on the observed stability of the genotype over time of observation

One of the ways to identify the best genotype is by observing the pattern of interaction between genotypes and the environment by using AMMI (Additive Main Effect and Multiplicative Interaction) analysis. Various multi-location studies using AMMI analysis have been widely reported [1–7]. AMMI analysis is a multi-location experimental data analysis method that combines an additive variance analysis for the main effect of treatment and principal component analysis for the interaction effect [8]. The advantage of the AMMI method is that it is able to increase the efficiency of selecting the best genotype by looking at the pattern of interaction relationships between genotypes and their environment using biplots [9]. AMMI can be used for multi-time tests, by viewing experiments between locations as experiments between times, so that the stability of each genotype can be revealed at each observation time. To date, there have been many research reports on the stability of results between locations, however the stability between time is not yet complete. The objective of this study is to disclose tea genotypes that are stable in producing peko shoots and adapt over several observation periods.

2. Materials and Methods

The study was carried out in Pemandangan, Tambi Wonosobo Regency, Central Java Province, Indonesia, namely an area with an altitude of 1,750 m above sea level, with a type B climate in accordance with the Schmidt-Ferguson classification, the rainfall ranging from 4 - 440 mm/day with the number of rainy days between 1 – 21 days, the temperature ranges from 10-23^{0}C with the humidity of 70-90%, the soil type of Regosol with pH value of 4.82, the location coordinates Lat: -7^{o} 16' 09.52" Long: 109^{o} 58 '18.06".

The study used a Randomized Block Design (RBD) in four groups. The factor of time as a location factor; In this case, the times can be assumed to be independent of each other. The treatment factors included 9 tea genotypes, namely GMB 3, GMB 4, TRI 2024, TRI 2025, Tambi 1, Tambi 2, Cin 143, Kiara 8, and RB 3, each of which was repeated four times. A total of 20 tea bushes were planted in each plot (3.75 × 4.80 m) with a distance between bushes of 120 × 75 cm.

Plant maintenance in this experiment was carried out in accordance with the Standard Operating Procedures for tea cultivation [10]. The plants are fertilized with Urea (high Nitrogen content), triple super phosphate, and potassium chloride (ratio 2:1:1). Fertilization is carried out twice, namely in April with a dose of 25 grams and in August with a dose of 20 grams. Picking is carried out according to a picking cycle of ± once in 3 week time.

The observations were carried out at the third year of trimming against the response of the percentage of peko shoots to bird shoots of the nine genotypes which were observed at six different times each from April to August 2017. The observations on the quality of the results included the weight of active shoots, the weight of dormant shoots, and the comparison of the active shoot weights and the weight of inactive (dormant) shoots of 100 gr of wet weight of leaves per plot taken randomly.

The mean difference test for all parameters was analyzed using analysis of variance (ANOVA).

3. Results and Discussion

The highest average percentage of peko shoots based on observation time was at P6, namely 53.7, and the lowest was at P4, 24.7 (Figure 1).

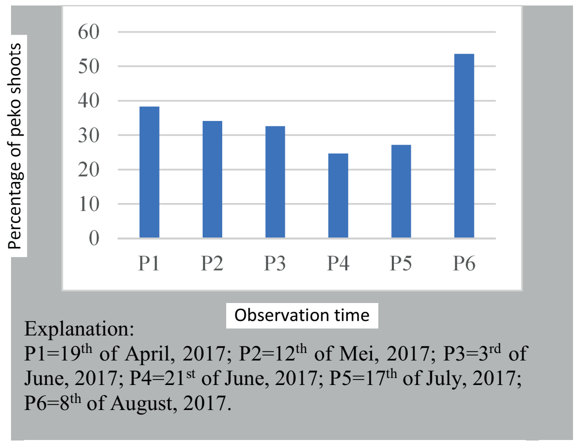
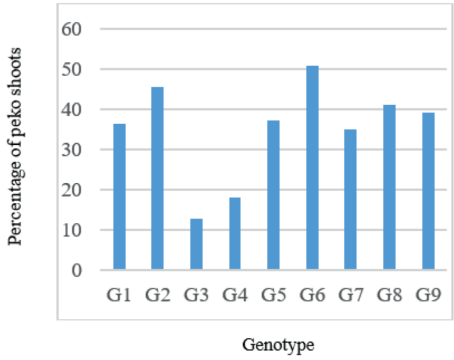


Figure 1: Average percentage of peko shoots based on time.

The highest average percentage of peko shoots based on the type of genotype was in Tambi 2 at 50.7 and the lowest was in TRI 2024 (12.7). The greater the number or dry weight of peko shoots, the better the quality of the tea shoots and the best grade of tea is produced [11]. Tambi 2 is able to produce better quality shoots compared to other genotypes. TRI 2024 produces shoots of lower quality than other genotypes. The average pattern according to genotype can be seen in Figure 2.



Explanation:
G1 = GMB 3, G2 = GMB 4, G3 = TRI 2024, G4 = TRI 2025, G5 = Tambi 1, G6 = Tambi 2, G7 = Kiara 8, G8 = Cin 143, G9 = RB 3

Figure 2: Average percentage of peko shoots based on genotype.

The peko shoot percentage data analyzed has met the assumptions of analysis of variance, namely the normality of error, the homogeneity of variance and the freedom of error at a significance level of 5%. By using the Kolmogorov-Smirnov test the response has a p-value of 0.150 which is greater than alpha, meaning that it can be said that the error is normally distributed. Bartlett's test was used to test the homogeneity of variance, which resulted in a p-value of 0.154 which was greater than alpha so it could be said that the error had a homogeneous variance. Apart from that, considering that a distribution plot that did not form a pattern meant that the errors could be said to be independent.

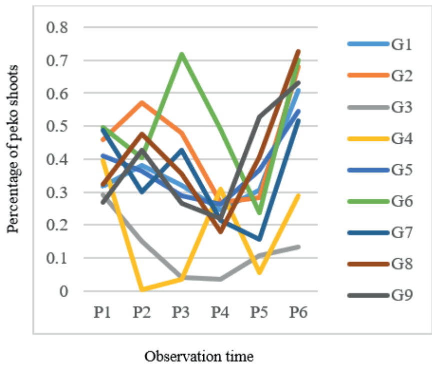
The results of the analysis of the combined variance of the response to the percentage of peko shoots are presented in Table 1. Based on the p-value in the table, information is obtained that the main effect and the interaction effect of the response have a significant effect at the 5% real level. A significant main effect of genotype means that there is at least one genotype that responds differently to other genotypes, and the same goes for the main effect of time. The significant interaction effect between time and genotype indicates differences in results from genotypes observed at different times. Therefore, the AMMI method can be used to classify genotype stability.

The results of the combined analysis of variance, the factors of time, the genotype and the interaction of time and genotype show an influence on the response variable, with a very small p-value (0.000). With the influence of the factors, the genotype stability was then tested at each time. The coefficient of determination of the ANOVA model is 78.39%, indicating the suitability of the model for variations in the response variables. The existence of an interaction effect shows that the differences in the average percentage of peko shoots between genotypes are not all the same at different times. It is necessary to reveal further which types of genotypes are stable and which are unstable over time.

Table 1: Analysis of combined variance of the percentage of peko shoots.

Sources of Variance	Degree of freedom	Sum of Squares	Mean Square	F	P -- Value
Genotypes	8	2.899	0.362	29.60	0.000
Time	5	1.918	0.384	31.32	0.000
Group	3	0.053	0.018	1.44	0.234
Genotype*Time	40	2.193	0.055	4.48	0.000
Error	159	1.947	0.012		
Total	215	9.010			

Figure 3 presents the average values of the response variables at various observation times. In Figure 3, there appears to be an interaction between genotype and time, which is visible in the non-parallel line pattern. This shows that the effect of genotype on the percentage of peko shoots produced depends on the time of observation, as well as the effect of time on the percentage of peko shoots depending on the genotype.



Explanation:
P1 = 19th of April, 2017; P2 = 12th of May, 2017; P3 = 3rd of June, 2017; P4 = 21st of June, 2017; P5 = 17th of July, 2017; P6 = 8th of August, 2017.
G1 = GMB 3, G2 = GMB 4, G3 = TRI 2024, G4 = TRI 2025, G5 = Tambi 1, G6 = Tambi 2, G7 = Kiara 8, G8 = Cin 143, G9 = RB 3

Figure 3: Interaction plot between time and genotype.

Based on the decomposition of the singular values of the matrix of estimated interaction effects on the response, a total of six non-zero characteristic roots are produced. This means there are six main components of interaction (KUI) that are considered for use.

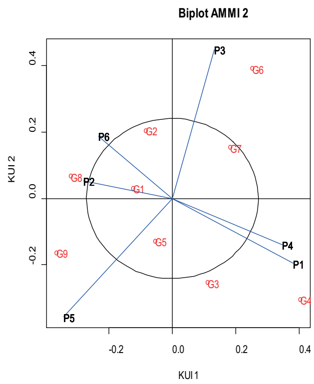
Based on the postdictive success method, namely KUIs that are significant in the F-test analysis of variance, the number of KUIs that are significant at the 5% significance level in Table 2 are three KUIs, namely KUI1, KUI2, and KUI3. By using three KUIs, it is possible to explain 94.96% of the diversity, while thediversity that could not be explained by the model was 5.04%. Therefore, the AMMI-2 biplot can then be used.

Table 2: AMMI analysis of variance based on the combined response of the percentage of peko shoots.

Sources Variance	Degree of freedom	Sum of Squares	Mean Square	F	P-Value
Time	5	1.918	0.384	31.32	0.00
Genotype	8	2.899	0.362	29.60	0.000
Group	3	0.053	0.018	1.44	0.234
Time*Genotype	40	2.193	0.055	4.48	0.000
KUI1	12	1.136	0.095	7.73	0.000
KUI2	10	0.719	0.072	5.87	0.000
KUI3	8	0.228	0.028	2.32	0.022
Deviation	12	0.110	0.021	1.74	1.000
Error	159	1.947	0.012		
Total	215	9.010			

The AMMI-2 biplot provides information regarding the interaction structure of genotype with observation time. The AMMI-2 biplot is based on KUI1 and KUI2 with an explainable interaction diversity of 84.59%. The genotypes GMB 3, GMB 4, Tambi 1, and Kiara 8 are stable genotypes at all observation times because they are in an ellipse. However, only the GMB 3 and Tambi 1 genotypes are believed to have higher stability because they are closer to the center point of the biplot, meaning that these genotypes have stable peko shoot productivity at all observation times. GMB 3 and Tambi 1 are superior varieties of assamica tea and sinensis tea respectively with potential yields of 4.25 tonnes/ha/year and 2.20 tonnes/ha/year [12,13].

According to Fentie et al. [14], in the AMMI-2 biplot analysis, genotypes and environments located far from the center point of the biplot (point 0.0) were more responsive. Other genotypes that are outside the ellipse can be said to be unstable, these genotypes tend to interact at certain observation times or specific genotypes. Based on Figure 4, the RB 3 genotype can interact well at the P5 observation time, meaning that the RB 3 genotype is specific at the P5 time. The TRI 2024 and TRI 2025 genotypes are specific at the P1 and P4 observation times. The Tambi 2 genotype is specific at the time of P3 observation. The Cin 143 genotype is specific at the observation time of P2.



Explanation:
P1 = 19th of April, 2017; P2 = 12th of May, 2017; P3 = 3rd of June, 2017; P4 = 21st of June, 2017; P5 = 17th of July, 2017; P6 = 8th of August, 2017
G1 = GMB 3, G2 = GMB 4, G3 = TRI 2024, G4 = TRI 2025, G5 = Tambi 1, G6 = Tambi 2, G7 = Kiara 8, G8 = Cin 143, G9 = RB 3

Figure 4: Biplot of AMMI-2 KUI 1 with KUI 2 on the combined response of peko shoot percentage.

4. Conclusion

AMMI analysis of the percentage response of peko shoots produced four genotypes within the ellipse, namely genotypes GMB 3, GMB 4, Tambi 1, and Kiara 8. GMB 3 and Tambi 1 are genotypes that have a stable percentage of peko shoots at all times. RB 3 is specific at the observation time of P5; TRI 2024 and TRI 2025 are specific at the observation time of P1 and P4; Tambi 2 is specific at the observation time of P3, and Cin 143 is specific at the observation time of P2. The stable genotypes could be recommended for further development.

References

[1] Sousa LB, Hamawaki OT, Nogueira APO, Batista RO, Oliveira VM, Hamawaki RL. Evaluation of soybean lines and environmental stratification using the AMMI, GGE biplot, and factor analysis methods. 2015;

[2] Hermeto LC, DeRossi R, Oliveira RJ, Pesarini JR, Antoniolli-Silva AC, Jardim PH, et al. Effects of intra-articular injection of mesenchymal stem cells associated with platelet-rich plasma in a rabbit model of osteoarthritis. Genet Mol Res. 2016 Sep;15(3):gmr-15038569.

[3] Rodrigues PC, Monteiro A, Lourenço VM. A robust AMMI model for the analysis of genotype-by-environment data. Bioinformatics. 2016 Jan;32(1):58–66.

[4] Vaezi B, Pour-Aboughadareh A, Mohammadi R, Armion M, Mehraban A, Hossein-Pour T, et al. GGE biplot and AMMI analysis of barley yield performance in Iran. Cereal Res Commun. 2017;45(3):500–11.

[5] Tena E, Goshu F, Mohamad H, Tesfa M, Tesfaye D, Seife A. Genotype× environment interaction by AMMI and GGE-biplot analysis for sugar yield in three crop cycles of sugarcane (Saccharum officinirum L.) clones in Ethiopia. Cogent Food Agric. 2019;5(1):1651925.

[6] Kendal E, Karaman M, Tekdal S, Doğan S. Analysis of promising barley (Hordeum vulgare L.) lines performance by AMMI and GGE biplot in multiple traits and environment. Appl Ecol Environ Res. 2019;17(2):5219–33.

[7] Enyew M, Feyissa T, Geleta M, Tesfaye K, Hammenhag C, Carlsson AS. Genotype by environment interaction, correlation, AMMI, GGE biplot and cluster analysis for grain yield and other agronomic traits in sorghum (Sorghum bicolor L. Moench). PLoS One. 2021 Oct;16(10):e0258211.

[8] Mattjik AA, Sumertajaya IM, Silvianti P. Klasifikasi Genotipe Pada Data Tidak Lengkap Dengan Pendekatan Model AMMI. In: Forum Statistika dan Komputasi. 2007.

[9] Crossa J. Statistical analyses of multilocation trials. Adv Agron. 1990;44:55–85.

[10] PPTK. Petunjuk Kultur Teknis Tanaman Teh. Bandung: Pusat Penelitian Teh dan Kina (PPTK) Gambung; 2006.

[11] Wijoseno G, Indradewa D, Putra ET. Potensi Hasil dan Toleransi Curah hujan beberapa Klon Teh (Camelllia sinensis (L.) O. Kuntze) PGL di Bagian Kebun Kayulandak, PT. Pagilaran. Vegetalika. 2012;1(3):64–77.

[12] Kementan. -. Kepmentan RI No. 266/Kpts/KB.230/4/88; 1998.

[13] Kementan. Kepmentan RI No. 157/Kpts/KB 010/2/2018. Kepmentan RI No. 157/Kpts/KB 010/2/2018; 2018.

[14] Fentie M, Assefa A, Belete K. AMMI analysis of yield performance and stability of finger millet genotypes across different environments. World J Agric Sci. 2013;9(3):231–7.