Stability of fruit and bunch of mapanget tall and Indonesia coconut hybrid with several planting distance using AMMI model and GGE biplot analysis

Y Matana1*, Miftahorrachman1, M Nur1 and M R Romadhon1

1Indonesian Palm Research Institute,Jl. Raya Mapanget, Mapanget Kotak Pos 1004 Manado 65001, Telp: 0431 – 812430, Fax: 0431 – 812017.

*Email: yulianusmatana@yahoo.com

Abstract. Coconut plantations with new system of planting distance allow wider use of distance under the coconut than the conventional planting distance. Evaluation stability of Mapanget coconut (DMT) and KHINA hybrid coconut at various planting distance systems can be used as a recommendation for the development of coconuts with new planting distance in the most suitable environmental conditions. The purpose of this study was to determine the stability of the yields of DMT and KHINA grown with various distance models for five years observation. The experiment was arranged in a factorial experiment design consists of 8 treatments with 2 replications, in the Mapanget Experimental Garden, North Minahasa Regency, North Sulawesi Province, for 5 years from 2014 to 2018. The results showed that the combined analysis variance was significantly different (F < 0.05) both GXE interaction for the number of fruits, while the character number of bunches is not different. The results of AMMI Biplot showed that Khina coconut with the most stable distance of 9 x 9 m followed by Khina coconut with a distance of 5x16 for land use under coconut plants with intercropping suggested using a distance of 5x16 m.

Keywords: AEA, biplot analysis, GxE, number of fruit, principal component

1. Introduction

Increased income of coconut farmers can be increased through the use of land between coconut trees. Setting the distance of coconut planting is very important to maximize land use between coconuts. Planting intercropping can maximize land use between coconuts. Intercropping can also improve the reduced carbon stock [1]. In addition, the physical and biological properties of the soil between coconut trees can be improved with the cultivation of the land.

The coconut planting distance system is still traditional with a spacing of 8.5 x 8.5 meters triangular and 9 x 9 meters square, it is not possible to use it for intercropping throughout the year starting from young coconut to mature coconut. For this reason, we need a distance pattern and a new planting system that allows farmers to cultivate land under coconut plantation throughout the year. Indonesia Palm Research Institute has produced a new coconut planting distance system that enables farmers to cultivate intercrops to increase their income and not depend only from coconut. The distance and planting system are 5 x 3 x 16 m, 5 x 16 m, and 5 x 12 m.

The diversity of environmental factors between locations and over several years of growth has been reported in oil palm while in coconut information is rarely available. According to [2], climate change will have an impact on agriculture, especially on plant growth and yields. According to [3], analysis of
interactions between genotypes and environment and other agroecological conditions will help obtain information about the adaptability and stability of genotype appearance.

[4], stated yield stability depends on plant characteristics such as understanding of environmental stress. According [5], G x E interaction is a major concern in plant breeding for two main reason. Firstly, they can reduce progress rate of selection. Secondly, they make cultivar recommendations difficult because it is statistically difficult to interpret the main effect [6], it fact that the genotypes performing well under a particular growing condition may or may not perform well over other environment due to genotypes-environments interaction (G x E).

[7]; [8]; explain that measurement of G x E interaction is important because it can be used to achieve breeding targets such as the selection of mother palm and recommendations for cultivars that adapt in an area. Producers of varieties are usually interested in cultivars that are consistent in their yield in various growing environmental conditions, therefore plant breeders test several treatments in several environments before they are released for planting by farmers [9]. According to [10], the interaction of genotypes with the environment is very useful in measuring the appearance and stability of genotypes in plant breeding programs.

According to[11], agricultural products are influenced by environment that generally lead to wide variation in yield, both among years in a location and among location in a single year or, even further, between location and years. [12] stated that yield stability is one of the valuable properties of a genotype that will be released as a variety.

In the last periods, biplot has been widely used in analyzing interactions between genotype and environment. A new method called GGE biplot has been developed based on various biplot visualization techniques for various case studies involving treatment and environmental data. The GGE biplot analysis has turned into a comprehensive GE data analysis system that can answer many questions related to GE interaction. The use of the GGE biplot system has expanded to the analysis of data relating to visual breeding [13]. GGE biplot is how the genetic stability of genotypes tested in various environments, which test environment can provide the best test results, and what genotypes are suitable for a particular environment, and many more. The purpose of this study was to evaluate the performances of DMT and Khina coconuts on four planting distance models over five years of observation; determine the possibility of different environmental condition in the DMT and Khina coconuts; and identify the best coconut growth in each environment.

2. Material and methods

2.1. Experimental Sites, Treatments and Design

The trial consists of two coconut cultivars representing each of tall coconut and hybrid coconut as follows: Mapanget Tall (DMT) and Khina hybrid (Khina) 18-22 years old. The cultivars were grown during five growing seasons at the experimental field of Indonesia Palm Research Institute. The field trial was arranged in randomized complete block design with eight treatments and two replications. Each plot consists of 45 plants. For maintenance, using fertilizers of ponska (compound fertilizer) with dosage 1300 gr palm\(^{-1}\) year\(^{-1}\) and urea with dosage 200 gr palm\(^{-1}\) year\(^{-1}\). Parameters observed are number of fruit per palm per year and number of fruit bunch per palm per year. The treatments and five growing seasons (rain fall) with their codes are in Table 1 and Table 2.

2.2. Statistical Analysis

Number of fruit and number of fruit bunch data combined across the five years observation were subjected to AMMI analysis of variance to determine genotype with several planting distance and years main effect, and genotype x years of observation interaction effects. The mean yields of genotypes in each year and across years and their first interaction principal component axis values were also analysed. The AMMI and GGE biplot models were used to identify genotype stability, which genotype (s) performed best in which environment (s), and rank the genotypes on high yield and stability. Analysis of variance was carried out using the R i386 3.5.2 Program. If the F test shows
the significant effect of the treatment and interaction of G X E, it is continued with G X E interaction analysis using the AMMI Model analysis with PBTools software.

Table 1. Two genotypes in four planting distance.

| No. | Genotypes with 4 planting distance | Code       |
|-----|-----------------------------------|------------|
| 1.  | DMT 9 x 9                         | DMT 9X9    |
| 2.  | DMT 5 x 3 x 16                    | DMT 5x3x16 |
| 3.  | DMT 6 x 16                        | DMT 6x16   |
| 4.  | DMT 5 x 12                        | DMT 5x12   |
| 5.  | KHINA 9 x 9                       | KN 9x9     |
| 6.  | KHINA 5 x 3 x 16                  | KN 5x3x16  |
| 7.  | KHINA 6 x 16                      | KN 5x16    |
| 8.  | KHINA 5 x 12                      | KN 5x12    |

Table 2. Years of Climate Data Observation

| No. | Years | Rain fall (mm) | Code |
|-----|-------|----------------|------|
| 1.  | 2014  | 2866           | 1    |
| 2.  | 2015  | 1787           | 2    |
| 3.  | 2016  | 3231           | 3    |
| 4.  | 2017  | 4289           | 4    |
| 5.  | 2018  | 2947           | 5    |

3. Results and discussion

3.1. Combined analysis variance on number of fruits and number of fruit bunch

Breeders and agronomic experts of coconut usually pay attention to differences in the growth of coconut variety both between locations and between seasons [14]. Variations between the environment and treatment can be tested by combined analysis variance and further analysis with AMMI. The AMMI analysis of variance for number of fruits and number of fruit bunch in four planting distance grown for five years growing season are presented in Table 3 and Table 4. For the number of fruits, variance components due to treatments was highly significant. one factor is the age of the coconut plant because the older the age of the coconut plant, the more fruit is produced. This large percentage indicated that the AMMI model could be partitioned effectively.

Table 3. Analysis of Variance for the number of fruit

| Source                | Degree of Freedom | Sum of Square | Mean of Square | F Value | Pr> F   |
|-----------------------|-------------------|---------------|----------------|---------|---------|
| Environment (Rain fall)| 4                 | 26316.11      | 6579.026       | 79.72   | <.0001**|
| Replication(Environnent)| 5               | 334.3856      | 66.87713       | 0.81    | 0.5503ns|
| Treatment (Planting distance)| 7             | 4360.923      | 622.989        | 7.55    | <.0001**|
| Environment*Treatment| 28               | 3265.257      | 116.6163       | 1.41    | 0.0051**|

Note: **= highly significance, *= significance, ns= not significance at α 5%.
Table 4. Analysis of Variance of number of fruit bunch

| Source                | Degree of Freedom | Sum of Square | Mean of Square | F Value | Pr>F   |
|-----------------------|-------------------|---------------|----------------|---------|--------|
| Environment (Rain fall)| 4                 | 84,499.25     | 21,124.81      | 20.06   | <.0001** |
| Replication (Environment) | 5               | 171,626.3     | 34,325.25      | 32.59   | <.0001** |
| Treatment             | 7                 | 19,857.5      | 2.836786       | 2.69    | 0.0242* |
| Environment*Treatment | 28                | 19,768.75     | 0.706027       | 0.67    | 0.8603ns|

Note: **= highly significance, *= significance, ns= not significance at α 5%.

[15] and [16] stated that the sum of squares of environment large indicates that the environment is diverse, with large differences between environmental averages causing variations in wheat production. [17] stated that if the interaction between treatments with the environment is significant, this indicates that the responses are inconsistent from the treatment to environmental changes. [18] stated that the large environmental influences to production showed that the environment spreads with differences in the large average between environments. Number of bunches are not significantly different, this is because there are not many differences in the number of bunches per plant so there is no difference significant.

3.2. Mean performance of DMT and KHINA with four planting distance

Table 5 presents genotypes and years observation means. Average number of fruit ranged from 122.78 fruits for the DMT 9x9 to 159.90 fruit for KHINA 5x16. Almost KHINA were above the grand mean (139.50), except KHINA 5x12, while, DMT genotype with all planting distance lower than the grand mean. Coconut tall Mapanget (DMT) starts to bear fruit at the age of 5 years. Round fruit shape, medium size, fruit color is generally brownish red. Average bunch production of 13 fruits per tree, the number of fruits is 7 fruits per bunch or an average of 90 fruits trees⁻¹ year⁻¹. Optimal copra production is 3.3 tons ha⁻¹ year⁻¹, oil content is 62.95%. Khina (KN) coconut starts to bear fruit at the age of 4 - 8 years. Round fruit shape, small fruit size, green fruit skin color, production of 13 fruits per bunch, optimal copra production is 5.01 tons ha⁻¹ year⁻¹, 60% oil content. According to [19] the yields are complex quantitative characters that are strongly influenced by environmental fluctuations, so the target of plant breeders will usually develop varieties with adaptability to the broad environment.

Table 5. Mean of number of fruits of eight treatments grown for five years growing season

| Treatment       | Years | Grand Mean |
|-----------------|-------|------------|
|                 | 1     | 2          | 3          | 4          | 5          | Total       |               |
| DMT 9 x 9       | 135.40| 137.30     | 139.60     | 116.40     | 94.40      | 613.90     | 122.78       |
| DMT 5 x 3 x 16  | 141.60| 141.00     | 151.50     | 127.20     | 90.60      | 686.60     | 137.32       |
| DMT 6 x 16      | 136.80| 139.00     | 155.40     | 116.90     | 78.80      | 640.20     | 128.04       |
| DMT 5 x 12      | 139.00| 148.30     | 142.90     | 115.10     | 76.50      | 620.80     | 124.16       |
| Khina 9 x 9     | 160.90| 167.20     | 200.40     | 166.80     | 120.80     | 785.50     | 157.10       |
| Khina 5 x 3 x 16| 155.40| 177.90     | 197.00     | 163.70     | 126.60     | 781.70     | 156.34       |
| Khina 5 x 16    | 159.60| 157.70     | 183.00     | 162.20     | 114.40     | 799.50     | 159.90       |
| Khina 5 x 12    | 148.70| 175.70     | 176.00     | 147.40     | 95.40      | 651.70     | 130.34       |

Coconut plants require an even amount of rainfall throughout the year of 2500-3500 mm. Observations indicate that there is a tendency for coconut production to increase with sufficient water requirements. In the third year, the amount of rainfall throughout the year was 3231 mm and was evenly distributed throughout the year so that the number of fruits was more than in other years.
3.3. Partition G X E on character of number of fruits
The main components used for biplot analysis are PC1 and PC2. These two main components were chosen because they have a cumulative percentage of around 80% (Table 6), so that it can be continued with an analysis of AMMI Biplot. The research by [20] state that the two main components (PC1 and PC2) produce 50% accumulated interactions of the main components, can be continued to AMMI Biplot to find out stable treatment; whereas according to [21], partitions of GxE interactions on the AMMI model show that the main components one and two reached 82.6%. So, from two main components selected (Table 6), could be continued to make biplot graph.

3.4. AMMI biplot PC1 and PC2
The AMMI Biplot analysis presents a graph that summarizes information on the main effect and interactions of effect between treatments and environment. The interaction of the main components 1 presents the Y axis as a treatment and environmental mean on the X axis. The treatment or environment located on the right side is high yielding while the treatment or environment is on the left side with low yield [22].

![AMMI Biplot](image)

**Figure 1.** Biplot of eight treatments and five growing season for number of fruits using genotypes and environment score

Figure 1. display the some numbers and letter-number combinations. Numbers show experimental environment numbers (1-5) and letter-number combinations indicate the number of treatments used in testing. Treatments that have character stability, should be near at the center point with ordinate (0,0) [23]. Based on Figure 1, the treatment that has yield stability in various environments is DMT 9x9. Other treatments show specific adaptability in each particular test environment. For example, KN 5x16 treatment adapts well to environment 4, but is less adapted to environment 3 because of the opposite direction of the vector. Conversely, KN 5x3x16 is adaptable well with high production of fruit in environment 3 but is less adapted to the environment 4.

The stability of each treatment in various environments is not an absolute requirement in selections. In addition to the stability of the actual results each treatment must also be seen to determine the best treatment. Because it can be stable with high yield or stable with low yield in various environments.
Although it has good stability in various environments, however, the DMT 9x9 has number of fruit below the average of all treatments in various environments (Table 4), so this treatment is not recommended. The treatment with the highest production value is KN 9x9 with a value of 785.50 number of fruits plant\(^1\). Based on the stability analysis, this treatment is categorized as unstable because it undergoes quite dramatic changes in production in several environments. In environments 1, 2, and 3, the number of KN 9x9 produced reasonably good, but decrease drastically in environments 4 and 5. Nevertheless the production of KN 9x9 is still better compared to other treatments in environments 1, 4, and 5. Thus, KN 9x9 can be recommended for planting in various environments.

while the best coconut is coconut in mapanget (DMT) with planting distance DMT 5x3x16.

### 3.5. AMMI analysis

Figure 2 presents the AMMI biplot with the genotype and environment main effects for number of fruits on the X-axis and PC1 scores on the Y-axis. The vertical line at the middle represents the grand mean of the number of fruits, while the horizontal line at the middle is PC1 value of zero [24]. The biplot revealed that treatments KN 9x9, KN 5x16, and KN 5x3x16, the highest produce of number of fruits in environments 1, 2, and 4. On the other hand the rest of treatments and environments were consider to be low yielding and were placed in left side of the biplot. According to [24], genotypes or environments which appear almost on the perpendicular line to the grand mean line have similar means, while those that appear almost on a horizontal line to the zero PC1 line have similar interaction pattern. Thus, treatments DMT 5x16 and DMT 5x3x16 had similar mean effects while DMT 5 x12, KN 5x3x16 and KN 5x16 showed the same interaction effect. For the environment (years), environment 1 had similar mean effect while environment 3 showed similar interaction effect. For environment 2, 4, and 5 no similar means and interaction effect, indicating that those environments were extremely different.

![AMMI Biplot]

**Figure 2.** AMMI biplot for number of fruits of treatments and years (main effect) versus stability of DMT and KHINA with four planting distance grown for five years growing season.
3.6. **GGE-BI PLOT analysis**

Figure 3 display the polygon view of which coconut with four planting distance were the best in which environment(s). The two principle component axes (PC1 and PC2) accounted for 89.2% of the total variation of number of fruits, in which total from PC1 51.3% and PC2 37.9% (Tab. 6). This result is in line with the result finding of [25], who were observed that two PC axes accounted for 77.39% of the total variation, consists of PC1 52.75% and PC2 24.64%. This is sufficient for determining stability of genotypes [25].

**Table 6.** Partition of G x E to several Principle Components (PC)

| GxE Partition | Percentage | Cumulative Percentage | Degree of Freedom | Sum of Square | Mean of Square | F value  |
|---------------|------------|-----------------------|-------------------|--------------|--------------|----------|
| PC1           | 51.3       | 51.3                  | 10                | 1674.7556    | 167.4756     | 2.22     |
| PC2           | 37.9       | 89.2                  | 8                 | 1236.6205    | 154.5776     | 2.05     |
| PC3           | 5.8        | 95.0                  | 6                 | 189.0010     | 31.5002      | 0.42     |
| PC4           | 5.0        | 100.0                 | 4                 | 164.8794     | 41.2198      | 0.55     |
| PC5           | 0.0        | 100.0                 | 2                 | 0.0000       | 0.0000       | 0.00     |

**Figure 3.** Polygon view of the GGE biplot showing which two coconut with 4 planting distance system has the best number of fruit in which years.

Based on Figure 3, showing a biplot which won where is one of the interesting features of GGE biplot to show the pattern of performance of each treatment in various environments. In environments 1, 3 and 5 the treatment of KN 9x9 and KN 5x16 has a very good performance compared to other treatments. However, KN 5x16 performance decreases when in environments 2 and 4. Conversely KN 5x3x16 has the best performance in environments 2 and 3 but not in other environments. The best performance sequence in environments 2 and 3 is KN 5x3x16 > KN 9x9 > KN 5x16. The conclusion from Figure 2 can be used to recommend the treatment of KN 9x9 and KN 5x16 most suitable for environmental 1, 3, and 5.
3.7. **GGE biplot analysis to determine ideal rank of treatment**

The results of the GGE Biplot analysis to rank ideal treatment based on the average number of fruits can be seen in Figure 4. Ideal treatment is the action with a vector approaching the center of the concentric circle and having the most AEA vector (Average Environment Axis) because it indicates besides having treatment stability it also has high yield. Based on the results of the biplot analysis, the ideal treatment chosen is the treatment of KN 9x9 because it is located at the center of the concentric circle. Based on the stability, the treatment of KN 5x16 and KN 5x3x16 has better stability compared to KN 9x9, but the production of KN 5x3x16 is not as good as KN 9x9 so the ideal treatment chosen is KN 9x9.

![GGE Biplot Genotype View for Number of Fruit Mean](image)

**Figure 4.** Treatment rating based on production mean criteria and stability to determine ideal treatment.

4. **Conclusion**

The results of observing the number of fruits for the DMT and KHINA coconuts on the four planting distance models over the five years of observation showed that the coconut fruit production at the KHINA 5x16 treatment was the highest, followed by the KHINA 9x9. The ideal treatment rating based on fruit production and yield stability, KHINA coconut at 9x9 m planting distance the most ideal and stable followed by KHINA 5x16 m. It is recommended to use KHINA coconut with 5x16 m planting distance for land use under coconut plantation, while for monoculture, better using KHINA coconut with 9 x 9 m planting distance.

**Reference**

[1] Herman and Dibyo 2004 Prosiding simposium iv hasil penelitian tanaman perkebunan. *Pulibangun* 416-424.

[2] Odewale J O, Ataga C D, Ago C, Odiowaya G, Okoye M N and Okole E C 2013 *Research Journal of Agriculture Environmental Management*. 21 10.

[3] Bose L K, Jambhulkar N N, Pande K and Singh O N 2014 *Chilean Journal of Agricultural Research*. 74 1-9.

[4] Zali H, Sofalian O, Hasanloo T and Asghari A 2016 *Agriculture Communication*. 41 8.

[5] Bueraheh N, Sdoodee S, Anotai J and Eksomtramage T 2018 *Australian Journal of Crops Science*. 12 1259-64.
[6] Bisawas A, Sarker U, Banik B R, Rohman M M and Talukder M Z A 2014 *Bangladesh J. Agril Res.* **39** 293-301.
[7] Ulaganathan V, Ibrahim S M, Gomathinayagam P and Gurusamy A 2015 *SABRAO J. Breed. Gen.* **47** 355-65.
[8] Karimizadeh R, Asghari A, Chinipardaz R, Sofalian O, and Ghaffari A 2016 *Turkish Journal of Field Crops.* **21** 174-83.
[9] Sayar M S, Anlarsal A E, and Basbag M 2013 *J.Field Crops.* **18** 238-46.
[10] Dia M, Wehner T C, Hassell R, and Price D S 2016 *Crops Sci.* **56** 1645-61.
[11] Suthamathi P and Nallathambi G 2016 *Elect. J. Plant Breed.* **71** 104-12.
[12] Dewi A K, Chosin M A, Triwidodo H, and Aswidinnoor H 2014 *Int. J. Agro. Agric. Res.* **5** 74-84.
[13] Lin C S, Binns M R and Leftkovitch L P 1986 *Crop Scie.* **26** 894-901.
[14] Odewale J O, Agho C, Ataga C D and Odiowaya G 2012 *World J. Agric. Sci.* **8** 229-33.
[15] Roostaei M, Mohammad R and Amri A 2014 *The Crop J.* **2** 154-63.
[16] Mohamed N E 2013 *J. Plant Breed. Crop Sci.* **7** 150-57.
[17] Ayaleneh T, Letta T and Abinasa M 2013 *Plant Breed.Seed Sci.* **67** 3-11.
[18] Mekonnen A, Mekbib F and Gashaw A 2019 *Journal of Agricultural Science and Practice.* **4** 9-19.
[19] Krishnamurthy S L, Pundir P, Singh Y P, Sharma S K, Sharma P C and Sharma D K 2015 *Journal of Soil Salinity and Water Quality,* **7** 98-106.
[20] Mengistu G, Daba C, Temesgen A, Lule D, and Galata N 2011 *East Afri. J. Sci.* **56**–11.
[21] Ferede M 2016 *East African Journal of Sciences.* **10** 15-22.
[22] Bach T, Alemerew S and Tadesse Z 2015 *Journal of Biology Agriculture and Healthcare* **5** 129-140.
[23] Shafii B and Price W T 1998 *Journal of Agricultural, Biological, and Environmental Statistics* **3** 335-45.
[24] Sesay S, Jalloh A B and Sama VA 2017 *Int. J. Plant Breed. Crops Sci.* **4** 291-9.
[25] Lolita M, Sukarsa I K G and Susilawati M 2019 *E-Jurnal Matematika* **8** 9-14.