International Journal of Development and Sustainability
ISSN: 2186-8662 – www.isdsnet.com/ijds
Volume 6 Number 11 (2017): Pages 1675-1688
ISDS Article ID: IJDS17082801

Productivity and stability of cassava promising clones based on the fresh tuber yield in six months using AMMI and GGE biplot

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Abstract

The aim of the trial was to analyze genotype x environment (G x E) interactions of cassava promising clones for tuber yield in six months based on AMMI (Additive Main Effects and Multiplicative Interaction) and GGE (Genotype and genotype x environment) biplot. The experiments were done on mineral soil in four different locations such as Lumajang (Inceptisol), Kediri (Entisol), Pati (Alfisol), and Tulangbawang (Ultisol). The experiments were done using a split-plot design, three replications. The plot size was a 5 m x 5 m. The main plots were different cultivation techniques, i.e. simple technology and improved technology, whereas the sub plot was cassava clones. The simple technology used plant population of 12.500 plants/ha and fertilizer of 93 kg N/ha; whereas in the improved technology, it used the same population density with slightly different fertilizers i.e. 93 kg N+ 36 kg P_2O_5 + 60kg K_2O/ha. The clones used were fifteen clones. Parameter recorded was fresh tuber yield (kg/ha) of six month old plants. The data were analyzed using the additive main effects and multiplicative interaction (AMMI) and GGE analysis. Research results can be seen that the mean tuber yield of CMM97006-44 was the highest in 6 months, followed by MLG 10311. The clones of CMM97002-183, Adira 4, and CMM97001-87 were identified as stable clones for tuber yield in 6 months. The environmental factors which important in determining stability of cassava promising clones based on the tuber yield in 6 months of using AMMI model were soil pH on Subsoil, the maximum air temperature in the first month, bulk density of soil on Topsoil, CEC of soil on Topsoil, N content of soil on Topsoil, and soil pH on Topsoil.

Keywords: Cassava; Clones x Locations Interaction; AMMI and GGE biplot; Tuber Yield

Cite this article as: Sholihin, S. (2017), "Productivity and stability of cassava promising clones based on the fresh tuber yield in six months using AMMI and GGE biplot", *International Journal of Development and Sustainability*, Vol. 6 No. 11, pp. 1675-1688.

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1. Introduction

Many research institutes (national and international level) have program for development new variety. The number of new variety is as target of the institution. New variety is important in increasing productivity of the plant. By using new variety that is superior than the existing variety, the productivity of plant will increase without additional production cost, so income of the farmer will increase. There is some phase for development of new varieties, one of them is multi-location trial. Plant environment is dynamic, it can be better or worse than the present and it can be predictable and unpredictable. Plant environment is varied and genotype interacts with environment to produce the phenotype. Ralated to the the various environments, the characteristic of new variety can be a wide adaptability or specific adaptability. Many methods are used in analysis interaction genotype and environment. Most of researchers only concentrate on the analysis of the stability as reported by Adie *et al.* (2010), Rasyad *et al.* (2012), Sumarno and Sutisna (2010), and Lestari *et al.* (2011). Information more detail about what kind of environment that affect the stability is limited. The AMMI (Additive Main Effects and Multiplicative Interaction**)** as proposed by Gauch (1992) is one of the methods for analysis of interaction genotype x environment. By using this method, the kind of the environment that effected the environment can be determined if the data about the environment are recorded. The other method used in analysis interaction genotype and environment is GGE (Genotype and Genotype x environment) method. Susanto *et al.* (2015) and Murti *et al.* (2014) used GGE method for analysis interaction genotype x environment.

Cassava (*Manihot eculenta* Crantz) is important crop in the world for food security. This crop is planted in tropical and sub-tropical countries. Many industries use cassava as raw material. The important thing for that industry is supplying the raw material continuously. To develop new variety that can be harvested early is one of the way to support the supply of the raw material continuously. A few promising clones have been identified from the cassava breeding program These clones are needed to be tested in various locations/environments conditions before releasing the promising clone as new varieties.

To release the new variety, the promising clone should be tested in some locations. The research objective was to know the fresh tuber yield and the stability of promising clones based on the fresh tuber yield in six months using AMMI and GGE biplot.

2. Materials and methods

The trials were done in four locations: Lumajang (Inceptisol), Kediri (Entisol), Pati (Alfisol), and Tulangbawang (Ultisol). The trials were done using a split plot design with three replications, and the plot size was a 5 m x 5 m. The main plots were simple technology and improved technology and cassava promising clones and check was as a sub-plot. Plant population of 12.500 plants/ha and fertilizer of 93 kg N/ha was used in the simple technology. Plant population of 12.500 plants/ha and fertilizer of 93 kg N+ 36 kg P_2O_5 + 60kg K_2O/ha was used in the improved technology. There were fifteen clones in this study. Data of fresh tuber yield in six months were taken in this study. The soil moisture in six months after planting, total rainfall, number of rainy days, the maximum and minimum air temperature, and the maximum and minimum air relative humidity, N, P_2O_5, K content of soil, CEC of soil, bulk density of soil, soil pH and soil texture on top-soil and sub-soil were recorded.

MSTAT (Michigan Statistic), version C software (released by Michigan State University) and IRRISTAT (International Rice Research Institute Statistic) software, version 5.0 (released by International Rice Research Institute) was used to analyze the data. PBTools software, (released by International Rice Research Institute) was used to analyze the stability of clones based on GGE Biplot.

3. Results and discussion

3.1. The combined analysis

Table 1. Combined ANOVA for 15 cassava clones, two technologies, and four locations for fresh tuber yield in six months

Source	Degree of freedom	Mean Square
Locations(L)	3	4432803080**
Replication/L	8	27224576
Technology (T)	1	349233722
T x L	3	156295776**
Error (a)	8	53596591
Clones (C)	14	253313773**
C x L	42	52946555**
T x C	14	26390204
T x C x L	42	13774431
Error (b)	224	17329679
C.V. (%)		18.45

*Note: ** : significantly different at 1 %*

The combined analysis of variance for tuber yield in six months is presented on Table 1. Interaction genotype x environment was significantly difference for the fresh tuber yield in six months. Presence of this interactions for the fresh tuber yield in six months were also reported (Sholihin and Sundari, 2008). Presence of Interaction genotype x environment for the other quantitative characters in cassava were also reported (Sholihin, 2015;

Sholihin, 2013; Sholihin *et al.,* 2016; *Sundari et al.,* 2010,). This interaction was because of various genotypes and environment. Based on Table 2, the fresh tuber yield in six months of clones fertilized by 93 kg N/ha was similar to that of clones fertilized by 93 kg N/ 93 kg N+ 36 kg P_2O_5 + 60kg K_2O/ha each location. Tuber yield of clones in 6 months in Lumajang ranged 20.78 – 38.020 t/ha, with mean 29.66 t/ha (Table 4). Tuber yield of CMM97006-44 was the highest. Tuber yield of CMM97001-12, UB 1-2, Adira4, and MLG 10311 were similar to CMM97006-44. Tuber yield in Pati, Jawa Tengah ranged 13.89 – 34.79 t/ha, with mean 27.093 t/ha. Tuber yield of CMM97006-44 was the highest. Tuber yield of CMM97001-12, UB 1-2, Adira4, and MLG 10311, Adira 1, CMM 97006-52 , and CMM97007-145 were similar to CMM97006-44. In Tulangbawang, Lampung, tuber yield ranged 11.61 – 23.60 t/ha, with mean 19.104 t/ha. Tuber yield of CMM97007-145 was the highest. Tuber yield ranged 14.64 – 27.4 t/ha, with mean 22.563 t/ha in Kediri, Jawa Timur. Tuber yield of CMM97006-44 was the highest. Tuber yield of CMM97001-12, UB 1-2, Adira4, and MLG 10311, CMM 97006-52, CMM97015-255, and CMM97007-145 were similar to CMM97006-44. The mean of the fresh tuber yield in six months of CMM97006-44 over locations was the highest (27.4 t/ha).

Table 2. Fresh tuber yield in six months with simple technology and advanced technology in some location

Location ;Technology	Fresh tuber yield (t/ha)
Lumajang; simple	28.41 a
Lumajang; advanced	30.79 a
Pati, simple	26.49 a
Pati, advanced	27.69 a
Tulangbawang; simple	11.80 b
Tulangbawang, advanced	17.11 ab
Kediri, simple	19.61 ab
Kediri, advanced	18.60 ab
LSD 5%	13.78

Table 3. Combined ANOVA for 15 cassava clones, two technologies, and four locations for fresh tuber yield in six months.

Source	Degree of freedom	Mean Square
Locations(L)	3	4432803080**
Error (a)	20	73234519
Clones (C)	14	253313773**
C x L	42	52946555**
Error (b)	280	17249418
C.V. (%)	18.41	

***Note**: ** : significantly different at 1 %.*

3.2. AMMI and GGE Analysis

The Interaction technology x genotype x location was not significantly different (Table 2). Besides that, application of simple technology and improved technology gave the same result in term of the fresh yield in six months (Table 2.). So factor of technology can be as a replication. As for AMMI analysis, there were 4 locations/environments, 6 replications, and 15 clones/varieties. Analysis of variance based on AMMI model for the fresh tuber yield in six months is presented on Table 3. Effect of interaction genotype x environment was significantly different on 1% level, with AMMI model, source of variance of genotype x environment interaction can be divided into some components, IPCA1, IPCA2, and IPCA3 for the fresh tuber in six months. Fifty nine percent of sum square of interaction was contributed by IPCA1, 25% by IPCA2, and 16% by IPCA3.

Data of the environments were taken. Analysis of correlation can be done to know the correlation between data of environments and IPCA score for the environments to give the meaning of dimension of IPCA. Result of correlation analysis of IPCA score for environment and data of environment is presented on Table 4-6. Based on this table, IPCA 1 correlated negatively with pH of sub-soil and the maximum air temperature during the first months of growing periond. IPCA1 corelated positively with the maximum air temperature during the fourth month of growing period. IPCA2 correlated positively with CEC (capacity exchange of cation) of soil on topsoil and N content on Topsoil. IPCA2 correlated negatively with total rainfall during the first months of growing period, bulk density of soil on topsoil and Soil pH on topsoil. So, the important environmental factors i.e pH of soil on Subsoil and the maximum air temperature during the first months of growing perionds, the maximum air temperature during the fourth month of growing period, CEC (capacity exchange of cation) of soil on topsoil and, total rainfall during the first months of growing period, bulk density of soil on topsoil, N content on topsoil and Soil pH on topsoil should be considered in the process of clone selection and evaluation for development of new variety.

Score of IPCA for four locations and the average of fresh tuber yield is given in Table 7. IPCA 1 score of Lumajang was -66.17, while in Tulangbawang was 96.15. IPCA 1 correlated negatively with the maximum air temperature during the first months of growing periond. The maximum air temperature during the first month of growing period was 32.47 ^{o}C in Lumajang, while in Tulangbawang, it was 32 ^{o}C. IPCA1 correlated positively with the maximum air temperature during the fourth month of growing period based on the data taken from station of climate, the maximum air temperature during the fouth month of growing period was 31.73 ^{o}C, while in Tulangbawang, it was 34.2 ^{o}C. Irikura *et al.* (1979) reported the presence of interaction between genotype and temperature. Increasing temperature from 20 ^{o}C to 40 ^{o}C will increase size of leave and rate of its development, however the capacity of leaf life will decrease. Temperature affects the storing of carbohydrate into tuber. Low temperature tend to retard the storing and the optimal temperature is the moderate temperature (Whyte, 1987).

IPCA 1 correlated negatively with pH of soil on sub-soil It meant that Lumajang had relatively high pH of soil on sub-soil, pH 6.15. while in Tulangbawang, it was, pH 4.9. Score of IPCA2 correlated negatively with Soil pH on topsoil. IPCA 2 score of Lumajang was -64.56, while in Pati was 69.84. Lumajang had relatively high Soil pH on topsoil (6.6), while in Pati, it was 4.7. Cassava is well adapted to acid soil, however, cassava can suffer from Al toxicity if level of exchangeable is low and soil pH is low(Howeler, 2002).

Score of IPCA2 correlated positively with CEC (capacity exchange of cation) of soil on topsoil, IPCA 2 score of Lumajang was -64.56, while in Pati was 69.84. Lumajang had relatively low CEC on topsoil (6.82me/100g), while in Pati, it was 23.9 me/100g. The value of CEC is important thing as indicator of soil fertility. Score of IPCA2 correlated positively with bulk density of soil on topsoil, Lumajang had bulk density of top-soil (1.435 g/cm^3), while in pati it was 1.08 g/cm^3). This parameter is useful in determining soil strength and soil compaction. Excessive soil compaction can impede root growth and therefore limits the amount of soil explored by roots thus reducing the plant's ability to take up nutrients and water. Score of IPCA2 correlated positively with N content of top-soil, Lumajang N content on Topsoil (0.06%). This was different from that Pati that had relatively high N content on Topsoil (0.14%). Those levels were classified as low level based on the criterion reported by Howeler (1981). Deficiency of nitrogen (N) will reduce the plant growth.

Score of IPCA2 correlated negatively with total rainfall during the fifth month of growing period, It meant that Lumajang had relatively high total rainfall during the first month of growing period (384 mm). This was different from that was in Pati had relatively low total rainfall during the first month of growing period (292 mm). Water is important for plants, the water is component for photosynthesis. Odubanjo *et al.* (2011) reported that tuber productivity of plants which received 100% available water 91% higher than that of plants which received 50% available water.

Score of IPCA for genotype and the average of the fresh tuber yield in six months in four environments is presented in Table 8. Biplot IPCA 1 and IPCA2 for genotype based on the fresh tuber yield in six months is presented in Figure 1. Based on this figure, it can be determined that clone/variety 4 (CMM97002-183), 14 (Adira 4), 1 (CMM97001-87), and 5 (CMM97002-36) were more stable than the other clones (MLG 10.311, UB 1-2, CMM97011-191, CMM97007-145, CMM97007-235, CMM97006-44, CMM97001-12, Adira 1, CMM97015-255, CMM97002-36, CMM97006-52 and Malang 2). However, based on GGE biplot, clone 11 (CMM97006-44) was the ideal genotype (shown by the bold dot in the center of the concentric area) Figure 2. Clone 11 (CMM

97006-44) had highest yield based on the average from all the the average and it is relatively stable and this clone is not bitter clone, while CMM97001-12, UB 1-2, Adira4, and MLG 10311, CMM 97006-52 , and CMM97007-145 are bitter clone.

Table 4. Fresh tuber yield in 6 months (t/ha) of cassava clones/varieties in four locations

No	clones	Fresh tuber yield in six months (ton/hectare)				
		Lumajang, Jawa Timur	Pati, Jawa Tengah	Tulangbawang, Lampung	Kediri, Jawa Timur	mean
1	CMM97001-87	30.970 cde	25.840 cde	13.650 bcd	19.170 abc	22.410 bcde
2	CMM97015-255	31.790 bcde	25.660 cde	15.760 b	20.420 abc	23.410 abcd
3	CMM97011-191	24.650 fg	20.880 e	13.720 bcd	14.130 de	18.340 ef
4	CMM97002-183	28.260 def	22.770 de	11.720 de	19.840 abc	20.650 cde
5	CMM97002-36	28.260 def	25.510 cde	16.650 b	16.670 cd	21.770 bcde
6	CMM97007-145	27.590 ef	29.800 abc	20.380 a	21.670 ab	24.860 abc
7	CMM97007-235	23.510 fg	28.280 bc	15.380 bc	17.550 bcd	21.770 bcde
8	CMM97006-52	28.490 def	29.590 abc	16.250 b	20.970 abc	23.830 abcd
9	Adira 1	20.780 g	13.890 abc	12.290 cde	11.610 e	14.640 f
10	Malang 2	23.850 fg	27.000 bcd	9.827 e	19.740 abc	20.110 de
11	CMM97006-44	38.020 a	34.790 a	15.030 bcd	21.740 ab	27.400 a
12	CMM97001-12	34.600 abc	30.300 abc	11.930 de	21.440 ab	24.570 abcd
13	UB 1-2	33.850 abcd	30.240 abc	12.210 cde	23.260 a	24.890 abc
14	Adira4	32.400 abcde	31.410 ab	16.960 b	17.590 bcd	24.590 abcd
15	MLG 10311	36.980 ab	30.430 abc	15.050 bcd	20.760 abc	25.810 ab
	mean	29.600	27.093	14.454	19.104	22.563
	LSD 5 %	5.682	5.346	3.364	4.394	4.720
	C.V. (%)	17	17	20	20	18

***Note**: The numbers in same columns with same letters are not significantly different at 5% level*

Table 4. Correlations value of characteristics of soil chemistry and IPCA score based on tuber yield in six months

IPCA	Characteristics of soil chemistry					
	N content on topsoil	N content on subsoil	P_2O_5 content on topsoil	P_2O_5 content on subsoil	K content on topsoil	K content on subsoil
IPCA1	0,032	0,053	0,044	-0,488	-0,793	-0,652
IPCA2	0,91*	0,308	0,269	-0,473	-0,609	-0,747

IPCA	Characteristics of soil chemistry				
	Soil pH on topsoil	Soil pH on subsoil	CEC of soil on topsoil	CEC of soil on subsoil	Soil moisture, 6 months after planting
IPCA1	-0,383	-0,922*	-0,154	-0,468	-0,253
IPCA2	-0,92*	-0,315	0,909*	0,88	0,625

Note:: significantly different at 5 % level*

Table 5. Correlations value of characteristics of climate factors and IPCA score based on tuber yield in six months

climate factor	IPCA1	IPCA2
No.of rainy days in first month of growing period	0.564	-0.547
No.of rainy days in second month of growing period	0.502	-0.387
No.of rainy days in third month of growing period	0.508	0.039
No.of rainy days in fourth month of growing period	0.725	-0.544
No.of rainy days in fifth month of growing period	-0.119	-0.367
No.of rainy days in sixth month of growing period	0.68	-0.258
Total rainfall in first month of growing period	0.281	-0.959*
Total rainfall in second month of growing period	0.52	0.389

Total rainfall in third month of growing period	0.635	0.683
Total rainfall in fourth month of growing period	0.598	-0.794
Total rainfall in fifth month of growing period	-0.013	-0.251
Total rainfall in sixth month of growing period	0.599	-0.289
The max. air temp. in first month of growing period	-0.921*	0.149
The max. air temp. in second month of growing period	0.545	0.324
The max. air temp. in third month of growing period	0.696	0.383
The max. air temp. in fourth month of growing period	0.914*	0.363
The max. air temp. in fifth month of growing period	0.547	0.513
The min. air temp. in first month of growing period	0.482	0.294
The min. air temp. in second month of growing period	0.423	0.181
The min. air temp. in third month of growing period	0.099	0.394
The min. air temp. in fourth month of growing period	0.27	0.389
The min. air temp. in fifth month of growing period	0.585	0.306
RH Max. in first month of growing period	0.754	0.596
RH Max. in second month of growing period	0.778	0.597
RH Max. in third month of growing period	0.74	0.631
RH Max. in fourth month of growing period	0.127	0.861
RH Max. in fifth month of growing period	0.66	0.703
RH Max. in sixth month of growing period	0.854	0.318
RH Min. in first month of growing period	0.774	0.395
RH Min. in second month of growing period	0.731	0.108
RH Min. in third month of growing period	0.487	-0.071
RH Min. in fourth month of growing period	0.855	-0.419
RH Min. in fifth month of growing period	0.025	0.037

*Note: *: significantly different at 5 % level*

Table 6. Correlations value of characteristics of soil physic and IPCA score based on tuber yield in six months

IPCA	Characteristics of soil physic							
	% sand on topsoil	% silt on topsoil	% clay on topsoil	% sand on subsoil	% silt on subsoil	% clay on subsoil	Bulk density of soil on topsoil	Bulk density of soil on subsoil
IPCA1	0.646	-0.534	0.042	0.327	-0.628	-0.124	-0.204	0.895
IPCA2	0.37	0.686	0.724	-0.598	0.009	0.797	-0.978**	-0.447

*** : nyata pada taraf 1 % level*

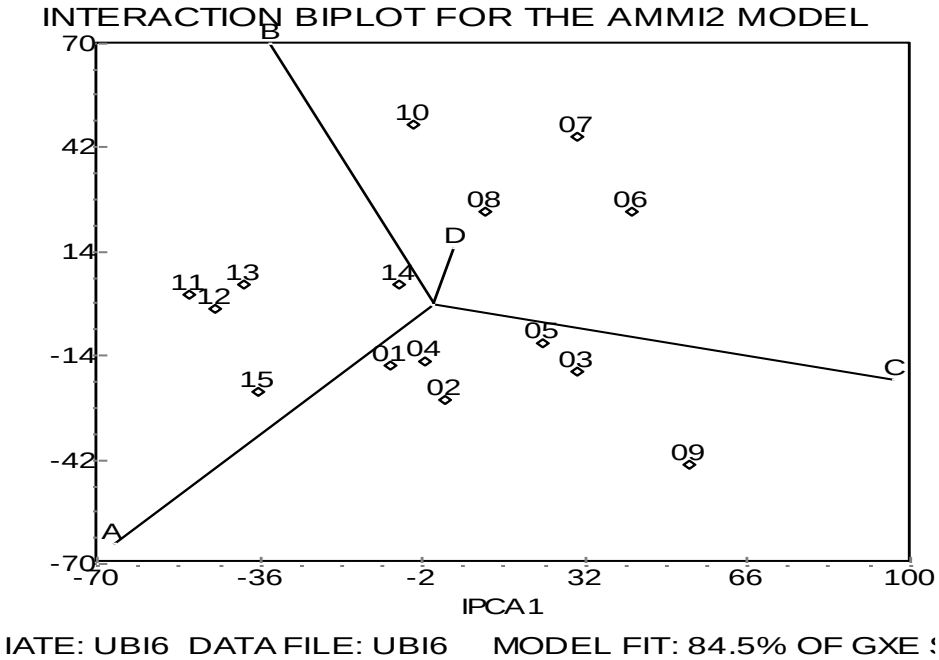

Figure 1. Biplot IPCA 1 and IPCA 2 for genotype based on the fresh tuber yield in six months (Note: *: significantly different at 5 % level)

1: CMM97001-87 6 : CMM97007-145 11: CMM97006-44

2: CMM97015-255 7 : CMM97007-235 12: CMM97001-12

3: CMM97011-191 8 : CMM97006-52 13: UB 1-2

4: CMM97002-183 9 : Adira 1 14: Adira 4

5: CMM97002-36 10: Malang 2 15: MLG 10.311

Table 7. IPCA score for locations and the average of fresh tuber yield in six months.

Locations	Fresh tuber yield t/ha	IPCA1	IPCA2
A.Lumajang.Inceptisol	29.601	-66.17	-64.56
B.Pati. Alfisol	27.093	-34.25 96.15	69.84
C.Tulangbawang. Ultisol	19.104	4.27	-20.21
D.Kediri. Entisol	14.454		14.93

Table 8. Score IPCA genotype and the average of the fresh tuber yield in six months

clone/variety	The fresh tuber yield (t/ha)	IPCA1	IPCA2
1. CMM97001-87	22.406	-8.457	-16.405
2. CMM97015-255	23.408	2.412	-25.620
3. CMM97011-191	18.344	30.244	-17.993
4. CMM97002-183	20.649	-1.577	-15.419
5. CMM97002-36	21.773	23.174	-10.847
6. CMM97007-145	24.858	41.950	24.539
7. CMM97007-235	21.180	30.049	44.876
8. CMM97006-52	23.826	11.383	24.572
9. Adira 1	14.645	53.716	-43.469
10. Malang 2	20.105	-3.973	48.315
11. CMM97006-44	27.396	-50.884	2.238
12. CMM97001-12	24.567	-45.477	-1.322
13. UB 1-2	24.893	-39.619	5.431
14. Adira 4	24.589	-6.630	4.933
15. MLG 10.311	25.806	-36.313	-23.829

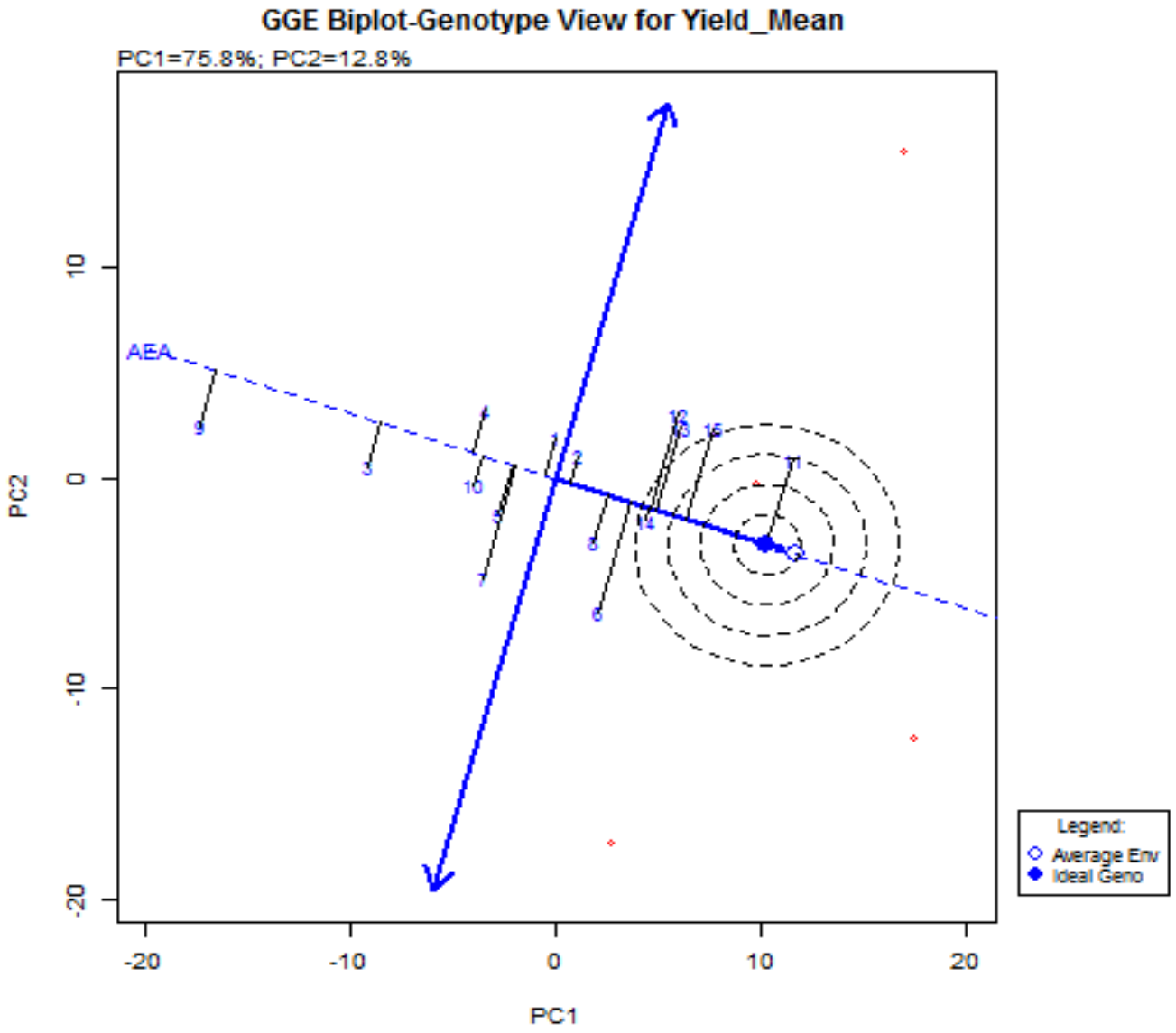

Figure 2. The stability of clones based on GGE biplot

Note: 1: CMM97001-87 6 : CMM97007-145 11: CMM97006-44

2: CMM97015-255 7 : CMM97007-235 12: CMM97001-12

3: CMM97011-191 8 : CMM97006-52 13: UB 1-2

4: CMM97002-183 9 : Adira 1 14: Adira 4

5: CMM97002-36 10: Malang 2 15: MLG 10.311

4. Conclusion

- The fresh tuber yield in six month of CMM97006-44 was the highest. followed by MLG 10311. Taste of cooked tuber of MLG 10311 is bitter, while taste of cooked tuber of CMM97006-44 1 is not bitter.
- Clone/variety 4 (CMM97002-183). 14 (Adira 4). 1 (CMM97001-87). and 5 (CMM97002-36) were more stable than the other clones (MLG 10.311, UB 1-2, CMM97011-191, CMM97007-145, CMM97007-235, CMM97006-44, CMM97001-12, Adira 1, CMM97015-255, CMM97002-36, CMM97006-52 and Malang 2) based on the fresh tuber yield in six months using AMMI models. However, clone 11 (CMM97006-44) was the ideal genotype based on GGE biplot.
- The important environmental factors that determine the stability of cassava tuber yield in six month-old were soil pH of Subsoil, minimum air temperature in first month of growing periods, the maximum air temperature in fourth month of growing periods, bulk density of Topsoil. CEC (capacity exchange of cation) of soil on topsoil. N content on Topsoil.

Acknowledgement

The author is grateful to Head of Agency for Agriculture Research and Development of Ministry of Agriculture for financial support.

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