RESEARCH ARTICLE

SABRAO Journal
of Breeding and Genetics
47 (4) 482-492, 2015

GENOTYPE-ENVIRONMENT INTERACTION ANALYSIS OF PEANUT IN INDONESIA

A. KASNO and TRUSTINAH

Research Institute for Legume and Tuber Crops, P.O. Box 66, Malang, Indonesia
Corresponding author's email: astantokasno@yahoo.com
Co-author's email address: trustinah02@yahoo.com

SUMMARY

Peanuts in Indonesia are mostly grown in Java, and other distributed in Sumatera, Kalimantan, and Papua which is dry and acid soil. This land is very diverse and has potential for agricultural production, especially intensification for food crops. Therefore specific varieties for these environments are necessary. Several field experiments were conducted in the dry seasons of 2011-2012 in 8 acid environments sites of Lampung Province, using a randomized block design with 3 replications. The research materials included 18 breeding lines from crosses and local varieties, and 2 checks of improved varieties (Jerapah and Talam 1). Stability analysis for pod yield was performed using regression technique and AMMI methods. Genotype G16 are stable according to regression and AMMI method and relatively stable to environmental changes. Stability analysis based on 3 stability parameters (mean yield, linier regression, and deviation from regression) and biplot graph indicated that the genotype G2, G3, G4, have stability below average followed with pod yield above general mean, and adapted on environment E1, E5 (favorable environments). Among those lines, genotypes G3 and G4 had the highest pod yields potential 4.05 t ha^{-1} and 3.73 t ha^{-1}, with an average yield 2.5 t ha^{-1} and 2.6 t ha^{-1} dry pod, respectively. These lines have been released as new varieties tolerant to acid soils.

Key words: Peanut (*Arachis hypogaea* L. Merr), genotype x environment interaction, acid soils, stability, adaptability

Key findings: Genotype environment interaction study of peanut in acid soil found that genotype G16 are stable and have broad adaptability, while the genotypes G3 and G4 have specific adaptability to favorable environment.

Manuscript received: November 13, 2013; Decision on manuscript: August 11, 2015; Manuscript accepted: September 19, 2015.

Communicating Editor: Bertrand Collard

INTRODUCTION

The environment is the sum of all external conditions affecting cultivar growth and development. Yield performance of crops is generally not consistent from one growing season to another, and from location to another location. This is caused by the existence of genotype x season x location interactions. This suggests that specific genotypes perform well in specific growing seasons, in certain locations. In other words, genotypes will have specific or broad adaptation.

The genotype x environment (G x E) interaction is the response of each cultivar to variations in the environments. Peanut genotypes planted in various environments or locations may interact with their environment. The occurrence of G x E interactions complicates the selection of genotypes with superior performance because the rankings of the test genotypes may change in different environments. There are possibilities to overcome G x E interactions: (1) developing cultivars with low G x E interaction by environmental stratification, defining areas in relatively homogeneous regions where genotypes specifically perform well, and (2) utilizing G x E interactions by developing stable varieties adapted to a wide range of environment.

Various methods have been used to analyze G x E interactions and stability across environments by using univariate and multivariate stability statistics (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966). Linear regression is the most commonly used procedure in the study of adaptability and stability, which are important in the recommendation of cultivars (Mekontcchou *et al*., 2006; Namorato *et al*., 2009; Acikgoz *et al*., 2009; Mothilal *et al*., 2010). Other methods for identifying cultivar with adaptability and stability have been developed and many multivariate techniques are available such as AMMI (Additive Main Effect and Multiplicative Interaction) and GGE (Genotype main effects and Genotype x Environment interaction) (Yan *et al*., 2000; Gauch, 2006). AMMI is a linear (additive effects) and bi-linear model (multiplicative effects) that integrates 2 statistical procedure, analysis of variance and principle component analysis. AMMI analysis can contribute to the identification of the most stable and productive genotype, to the recommendation of the region-specific cultivars, provide more precise estimates of genotypic responses, and an easy interpretation of the results in biplot graphs (Zobel *et al*., 1988). The biplot is useful tool to visually evaluate and interpret cultivar response patterns, environments, and the G x E interaction as was done by (Olievera and Godoy, 2006; Gurmu *et al*., 2009; Das *et al*., 2010; Escobar *et al*., 2011).

Harvested area of peanuts in Indonesia in 2013 reached 701.680 ha with an average productivity 1.35 t ha^{-1}, ranging from 0.76-1.69 t ha^{-1}. The crop harvested area of peanut was 72% in Java, and the remaining 28% is distributed in Sumatra, Kalimantan, Sulawesi, Maluku, and Papua, which are acid dry land and swamp (Mulyani *et al*., 2009; Statistics Indonesia, 2015). These land are very diverse and is a potential area for peanut cultivation. Research indicated that peanuts can still grow well in acid conditions, and there was a peanut germplasm accession that tolerant to acid soil at Al saturation above 30%. (Trustinah *et al.,* 2008; Trustinah *et al*., 2009). Survey conducted by Taufiq *et al*. (2004) in Lampung showed that dry land in Central Lampung and Tulang Bawang relatively acid (pH 5) with Al saturation from 24.5 to 30.2 %. The main problem in dry land in Central Lampung and Tulang Bawang are low pH, high saturation of Al, Fe, and the availability of P and K are low. Preliminary yield trial of 100 peanut genotypes on dry land in Central Lampung show that pod yield ranged from 1.35 to 3.57 t ha^{-1} (Trustinah *et al*., 2011). The aims of this study were to evaluate the genotype and environment interactions (G x E), stability, and adaptability of peanut genotype for pod yield on acid dry land.

MATERIALS AND METHODS

Research material consisted of 20 peanut genotypes includes of a cross between the varieties Gajah, Mahesa, Local Muneng, and Jerapah with ICGV 91279, ICGV 92088, J-11, ICGV 91278, ICGV 86680, two local varieties Pemalang, Madiun and 3 varieties Landak, Jerapah and Talam 1 (Table 1). Field trials were conducted in Lampung [South Lampung (Natar), Central Lampung Central (Rumbia), East Lampung (Rejobinagun and Sukadana), and North Lampung (Sungkai Utara)] (Table 2). All experiments were carried out during the dry season (DS) in 2011 and 2012 using a randomized block design with 3 replications. Peanuts were planted in the plot size (12 m^2) in 6 rows 5 m long with a spacing of 40 cm between rows and 15 cm within rows, and 1 seed/hole. Fertilizers were given with Urea, SP36, and KCl 45-90-90 kg ha^{-1}, respectively. Recommended package of practices were followed to raise the healthy crop. Plot yield was recorded and pod yield per hectare was calculated for the purpose analysis.

483

Table 1. List of peanut genotypes.

Code	Genotype	Pedigree/Origin
G1	MHS/91278-99-C-180-13-5	Mahesa/ICGV 91278
G2	G/92088//92088-02-B-2-9	Gajah/ICGV 92088// ICGV 92088
G3	G/92088/92088-02-B-2-8-1	Gajah/ICGV 92088// ICGV 92088
G4	G/92088/92088-02-B-2-8-2	Gajah/ICGV 92088// ICGV 92088
G5	J/J11-99-D-6210	Jerapah/J11
G6	P 9801-25-2	
G7	G/92088/92088-02-B-8	Gajah/ICGV 92088// ICGV 92088
G8	MHS/91278-99-C-174-7-3	Mahesa/ICGV 9278
G9	Jerapah	Jerapah
G10	J/91283-99-C-192-17	Jerapah/ICGV 91283
G11	MHS/91278-99-C-180-13-7	Mahesa/ICGV 91278
G12	M/92088-02-B-1-2	Local Muneng/ICGV 92088
G13	MLG 7720	Lokal Pemalang
G14	MLG 7638	Lokal Madiun
G15	GH02/G-2000-B653-54-28	GH 02/Gajah
G16	IC87123/86680-93-B-75-55-1	ICGV 87123/ICGV 86680
G17	IC87123/86680-93-B-75-55-2	ICGV 87123/ICGV 86680
G18	MLG 7932	Landak
G19	UNILA 2	Unila 2
G20	Talam 1	Talam 1

Table 2. List of locations of peanut adaptation trial.

Location	Village, sub-district,District	Year	Type of soil	Land type	Altitude (m asl)
E1	Negara Ratu, Natar, South Lampung	2011	Entisol	Dry land	95
E2	Restubaru, Rumbia, Central Lampung	2011	Entisol	Dry land	31
E3	Rejobinangun, Raman Utara, East Lampung	2011	Entisol	Dry land	23
E4	Bumiayu, Sukadana, East Lampung	2011	Entisol	Rainfed	31
E5	Negara Ratu, Sungkai Utara, North Lampung	2012	Entisol	Rainfed	23
E6	Negara Ratu, Natar, South Lampung	2012	Entisol	Dry land	95
E7	Restubaru, Rumbia, Central Lampung	2012	Entisol	Dry land	31
E8	Rejobinangun, Raman Utara, East Lampung	2012	Entisol	Dry land	23

Plant data observed in this experiment are: score foliar diseases (rust and leaf spot) at the 75 day after planting (DAP), harvest pod yield per plot (12 m^2), and characteristics of the soil. Rust and leaf spot diseases was observed at the age of 75 DAP refers to Subrahmanyam (1985) by using a scale from 1-9.

Data analysis: Pod yield data was subjected to analysis of variance separately for each environment and combined over environments. The statistical model used for ANOVA is:

$$Y_{ijk} = \mu + G_i + E_j + GE_{ij} + B_{k(j)} + \varepsilon_{ijk}$$

Where, Y_{ijk}=observed value of genotype I in block k of environment (location) j, μ = grand mean, G_i = effect of genotype i, E_j = environment or location effect j, GE_{ij} = interaction effect between genotype i and location j, $B_{k(j)}$ = the effect of block k in location (environment) j, ε_{ijk} = error (residual) effect of genotype I in block k of environment j. Environment were assumed to be random effects and genotypes were considered fixed effects. Bartlet's test of homogeneity of variances, the normality test for data, the ANOVA, mean separation were performed using MSTATC software (Michigan State University 1991). Analysis of the genotype x environment interaction (G x E), stability and adaptability refers to Eberhart and Russell (1966) calculated using Microsoft Excel program, and biplot analysis using package AMMI-R (STAT-IPB Version 1.0).

According to Eberhart and Russell (1966), genotype with high mean yield, low regression coefficients (b = 1) and non-significant deviation from regression ($S^2d = 0$) are the most stable. Genotypes with b > 1 are the ones which are specifically adapted to favorable environments, and genotypes with b < 1 are specially adapted to unfavorable environments.

RESULTS

The analysis of variance of 20 genotypes of peanut in 8 locations showed that all main effects (genotype and environment) and the interaction of genotype and environment for pod yield were significant. This mean indicated that the rank of peanut genotypes changed from location to locations. Combined variance analysis showed that location contributed to the largest variation, followed by the interaction between genotype and environment (G x E), and genotype contributed the smallest effect to the variation observed. Considering the sum of squares for treatment, about 74.5, 7.9, and 17.6% of the sum squares was explained by the environment, genotypes, and G x E interaction, respectively. AMMI analysis of dry pod of twenty genotypes in 8 environments shows that IPCA 1, IPCA 2, and IPCA 3 statistically significant ($P < 0.01$) and explaining 32.2, 22.4, and 15.1% of the G x E sum of square, respectively (Table 3).

Differences in soil fertility and acidity, and the resistance of peanut genotypes to disease (rust and leaf spot) contributed to the G x E interaction of peanut. Differences in soil pH were represented by soil analysis for South Lampung, Central Lampung, and East Lampung. Soil pH for 8 environments range between 4.5-6.4 which were classified as acid, with the level of Al saturation ranged from 1.1 (low) up to 36.3 (moderate) (Table 4).

Average yield of peanut genotypes at 8 environments ranged from 1.37 to 3.36 t ha^{-1}. Differences in soil fertility can be seen from the diversity of soil pH, availability of Al, Fe, Mn, and other elements (Table 4). From biplot AMMI 1 shows that 2 locations (E5 and E1) have pod yield above the general mean, while the lowest is E4 (Figure 1). Environment 5 (E5) characterized by pH 4.5 (acid), low Al saturation, higher soil fertility, and provide the highest average yield of 3.36 t ha^{-1}, while the E1 environment has a relatively acid soil, the element P is lower and Fe, Mn, and Al is higher than the location of E5. On the contrary, the location of E4 which has the lowest average yield (1.37 t ha^{-1}) has pH of 4.87 (acid), medium Al saturation, high content of Fe and Mn, and low soil fertility (Table 4 and 5).

Table 3. Combined analyses of 8 locations for peanut yield trial (dry Season of 2011-2012)

Source of Variation	Degree of freedom	Sum Square	Mean Square	F Test
Environment (E)	7	132.134	18.876	200.71**
Genotype (G)	19	14.073	0.741	1.60**
Interaction G x E	133	31.158	0.234	2.49**
IPCA 1	25	10.972	0.439	3.15**
IPCA 2	23	6.983	0.304	2.18**
IPCA 3	21	4.706	0.224	1.61*
Residual	64	8.147	0.493	
Error	318	44.259	0.139	

Table 4. Analysis of soils in South Lampung, Central Lampung and East Lampung.

Soil variable	Location/ Environment (E)							
	E1	E2	E3	E4	E5	E6	E7	E8
pH-H_20	5.08	6.09	5.58	4.87	4.5	5.2	5.8	6.4
C-organik (%)	233	3.53	1.94	2.67	0.89	1.17	0.92	0.66
P_20_5 (ppm)	15.2	218	110	8.41	41	22	141	65
Fe (ppm)	5.19	50.9	40.3	357.7	3.2	0.6	2.1	2.6
Mn(ppm)	27.57	5.19	7.65	39.83	1.3	113.4	0.3	0.2
K-dd (cmole/kg)	0.12	0.13	0.08	0.05	0.28	0.28	0.28	0.24
Ca-dd (cmole/kg)	0.98	3.32	1.88	0.63	1.34	3.67	3.99	2.37
Mg-dd (cmole/kg)	0.49	0.51	0.26	0.29	0.47	1.78	1.21	1.65
Na-dd (cmole/kg)	0.17	0.23	0.19	0.16	0.04	0.06	0.03	0.03
Al-dd (cmole/kg)	0.43	0.00	1.42	0.65	0.36	0.08	0	0.05
KTKe (cmole/kg)	2.5	4.4	3.9	2.8	2.8	6.2	5.6	4.5
Al saturation (%)	17.2	0.0	36.3	23.1	13.0	1.3	0.0	1.1
Base saturation (%)	87.6	95.7	98.0	63.3	90.2	94.7	98.7	97.3

The performance of pod yield between genotypes was also caused by differences in the resistance to diseases (rust, and leaf spot). All peanut genotypes tested could be considered as moderately-susceptible to leaf spot disease (Table 7). Responses of peanut genotypes to rust disease ranged from susceptible to resistant. When the response of peanut genotypes to rust disease showed a score of 3, the genotypes were classified as resistant, and 4 for moderate resistant to rust disease. There were five genotypes that were resistant (G2, G3, G4, G6, and G12) to rust disease, and the other peanut genotypes were categorized as moderately resistant to rust disease (Table 7).

The yield potential of peanut lines would depend on the environmental conditions/ location, and lines which were planted. In other words, peanut lines that grew well in 1 location were not necessarily the best performing lines when they were planted in another location, or the rank changed from location to location (Table 6). There were 9 genotypes of peanut (G1, G2, G3, G4, G6, G12, G14, G16 and G17) that had pod yield above the general mean (2.27 t ha^{-1}), and above the check varieties Jerapah and Talam 1. Genotypes G6, G12, G16, and G17 interacted positively with the environment E3 and E4, and interacted negatively with environments E1, E2, E5, E6, E7, and E8. While the genotype G1, G2, G3, G4, and G14 interact positively with environments E1, E2, E5, E6, E7, E8, and interacting negative with the environment E3 and E4 (Figure 1). The peanut lines G3 and G4 had the highest pod yield potential 4.05 t ha^{-1} and 3.73 t ha^{-1} dry pods, respectively. The average pod yields from 8 environments were 2.47 t ha^{-1} and 2.62 t ha^{-1} dry pods (Table 5).

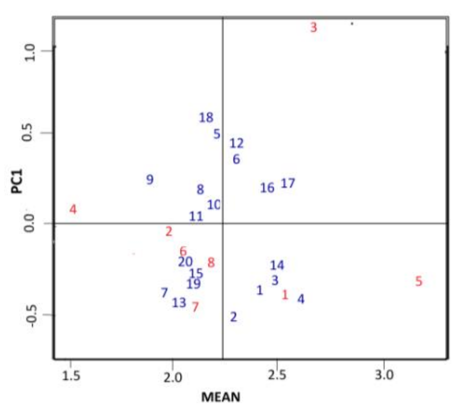

Figure 1. Biplot AMMI 1

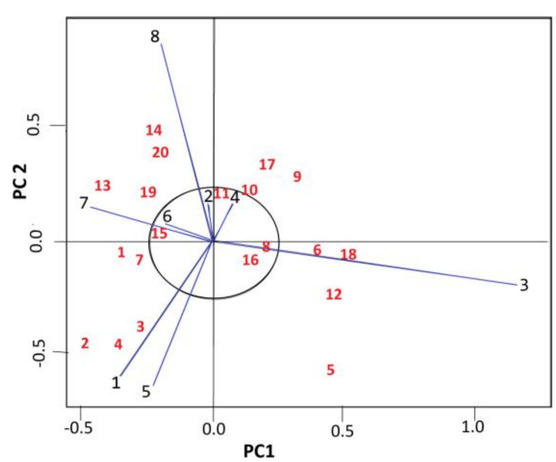

Figure 2. Biplot AMMI 2

Table 5. Pod yield of 20 peanut genotypes on acid soils at 8 locations (Dry seasons 2011 and 2012).

No	Genotype	Code	Pod yield (t/ha^{-1})									
			Location (Environment)									
			E1	E2	E3	E4	E5	E6	E7	E8	Mean	Potency
1	MHS/91278-99-C-180-13-5	G1	2.64	2.13	2.19	1.30	3.62	2.50	2.51	2.32	2.40	3.62
2	G/92088//92088-02-B-2-9	G2	2.85	1.92	1.89	1.43	4.08	2.09	2.14	2.07	2.31	4.08
3	G/92088//92088-02-B-2-8-1	G3	2.94	2.15	2.25	1.55	4.05	1.89	2.12	2.82	2.47	4.05
4	G/92088//92088-02-B-2-8-2	G4	3.67	2.35	2.51	1.30	3.73	2.41	2.63	2.37	2.62	3.73
5	J /J11-99-D-6210	G5	2.48	2.05	3.01	1.41	3.60	2.06	1.96	1.47	2.26	3.60
6	P 9801-25-2	G6	2.52	1.84	2.96	1.63	3.51	2.08	1.88	3.04	2.43	3.51
7	G/92088//92088-02-B-8	G7	2.34	1.78	1.84	1.28	3.13	1.66	2.21	2.34	2.07	3.13
8	MHS/91278-99-C-174-7 -3	G8	2.70	2.27	2.56	1.16	2.85	1.93	1.98	2.02	2.18	2.85
9	Jerapah	G9	2.04	1.8	2.33	1.32	2.68	1.62	1.70	2.02	1.94	2.68
10	J/91283-99-C-192-17	G10	2.62	2.18	2.46	1.34	2.89	2.28	1.83	2.36	2.25	2.89
11	MHS/91278-99-C-180-13-7	G11	2.23	2.11	2.27	1.47	2.95	2.10	2.14	2.02	2.16	2.95
12	M/92088-02-B-1-2	G12	2.44	1.85	3.13	1.60	3.51	1.97	2.18	2.12	2.35	3.51
13	720	G13	2.38	1.62	1.66	1.62	2.89	1.57	2.26	2.13	2.02	2.89
14	7638	G14	2.28	2.16	2.32	1.54	3.73	2.20	2.41	2.95	2.45	3.73
15	GH 02/G-2000-B-653-54-28	G15	2.52	2.01	2.03	1.33	3.16	1.86	2.21	2.09	2.15	3.16
16	IC 87123/86680-93-B-75-55-1	G16	2.69	2.04	2.83	1.24	3.59	1.95	2.36	2.78	2.44	3.59
17	IC 87123/86680-93-B-75-55-2	G17	2.39	2.49	2.76	1.46	3.73	2.08	2.16	2.91	2.50	3.73
18	MLGA 0306	G18	2.27	1.72	3.04	1.25	3.22	2.00	1.94	2.11	2.19	3.22
19	Unila 2	G19	2.23	1.83	2.1	0.93	3.17	1.96	2.60	2.30	2.14	3.17
20	Talam 1	G20	2.24	1.91	1.95	1.20	3.01	2.19	1.86	2.69	2.13	3.01
	Average ($t.ha^{-1}$) dry pod		2.52	2.01	2.40	1.37	3.36	2.02	2.15	2.35	2.27	
	Pod lowest ($t.ha^{-1}$)		2.04	1.62	1.66	0.93	2.68	1.57	1.70	1.47	1.94	
	Pod highest ($t.ha^{-1}$)		3.67	2.49	3.13	1.63	4.08	2.50	2.63	3.04	2.62	
	LSD		0.62	0.55	0.71	0.42	0.05	0.46	0.48	0.55	0.21	

Table 6. Rank of peanut pod yield across 8 environments.

No	Genotype	Code	Rank of peanut genotype on eight Environments								
			E1	E2	E3	E4	E5	E6	E7	E8	Average
1	MHS/91278-99-C-180-13-5	G1	6	7	14	13	6	1	3	10	8
2	G/92088//92088-02-B-2-9	G2	3	12	18	8	1	7	11	16	10
3	G/92088//92088-02-B-2-8-1	G3	2	6	13	4	2	16	13	4	8
4	G/92088//92088-02-B-2-8-2	G4	1	2	8	14	3	2	1	7	5
5	J /J11-99-D-6210	G5	10	9	3	9	7	10	15	20	10
6	P 9801-25-2	G6	9	15	4	1	9	8	17	1	8
7	G/92088//92088-02-B-8	G7	14	18	19	15	14	18	7	9	14
8	MHS/91278-99-C-174-7 -3	G8	4	3	7	19	19	15	14	17	12
9	Jerapah	G9	7	4	9	10	17	3	19	8	10
10	J/91283-99-C-192-17	G10	18	8	12	6	16	6	12	19	12
11	MHS/91278-99-C-180-13-7	G11	11	14	1	3	10	12	9	13	9
12	M/92088-02-B-1-2	G12	13	20	20	2	18	20	6	12	14
13	720	G13	15	5	11	5	4	4	4	2	6
14	7638	G14	8	11	16	11	13	17	8	15	12
15	GH 02/G-2000-B-653-54-28	G15	5	10	5	17	8	14	5	5	9
16	IC 87123/86680-93-B-75-55-1	G16	12	1	6	7	5	9	10	3	7
17	IC 87123/86680-93-B-75-55-2	G17	16	19	2	16	11	11	16	14	13
18	MLGA 0306	G18	19	16	15	20	12	13	2	11	14
19	Unila 2	G19	17	13	17	18	15	5	18	6	14
20	Talam 1	G20	20	17	10	12	20	19	20	18	17

Table 7. Rust and leaf spot disease scores of 20 peanut genotypes in 6 environments.

No	Code	Score of rust disease								Score of leaf spot disease							
		Environment						Ave-rage	Range	Environment						Ave-rage	Range
		E1	E2	E5	E6	E7	E8			E1	E2	E5	E6	E7	E8		
1	G1	2	2	7	4	4	5	4	2-7	4	5	7	6	6	3	5	3-7
2	G2	2	2	6	3	3	3	3	2-6	3	4	7	4	6	3	5	3-7
3	G3	2	2	5	3	3	4	3	2-5	3	4	7	5	6	3	5	3-7
4	G4	2	2	5	3	4	3	3	2-5	3	4	6	5	6	3	4	3-6
5	G5	2	2	4	3	4	5	4	2-5	4	5	7	6	7	3	5	3-7
6	G6	2	2	5	3	3	5	3	2-5	4	4	8	6	6	3	5	3-8
7	G7	2	2	5	3	4	6	4	2-5	3	5	7	5	7	3	5	3-7
8	G8	2	2	6	3	5	6	4	2-6	4	4	8	6	7	3	5	3-8
9	G9	2	2	4	3	6	7	4	2-7	4	4	8	5	7	3	5	3-8
10	G10	2	2	4	3	6	7	4	2-7	4	5	7	5	7	3	5	3-7
11	G11	2	2	5	4	5	6	4	2-6	4	4	8	6	7	3	5	3-8
12	G12	2	2	5	3	3	4	3	2-5	3	3	7	5	6	3	5	3-7
13	G13	2	2	5	4	5	7	4	2-7	4	4	8	6	7	3	5	3-8
14	G14	2	2	4	3	6	7	4	2-7	4	3	7	6	7	3	5	3-7
15	G15	2	2	5	3	6	5	4	2-6	4	4	8	6	7	3	5	3-8
16	G16	2	2	4	3	6	7	4	2-7	4	5	8	6	7	3	5	3-8
17	G17	2	2	4	3	6	6	4	2-6	3	5	8	5	7	3	5	3-8
18	G18	2	2	4	3	5	7	4	2-7	4	4	7	6	7	3	5	3-7
19	G19	2	2	4	3	4	7	4	2-7	4	4	6	5	7	3	5	3-7
20	G20	2	2	4	3	5	7	4	2-7	4	5	7	5	7	3	5	3-7

Genotype x environment interactions, and the interaction of genotype x environment (linear) were significant for yield, suggesting that the G x E interaction as a whole which is linear with the environmental index is closely correlated (Tables 8 and 9). The coefficient of determination varied from 75 to 95% for pod yield, with an average of 84%. The coefficient of determination (R) average regression of pod yield on environmental index was due to the influence of the environment (Table 9).

Stability parameters b_i and S^2_{di}, were different from 1 and 0 showed that the genotype are not stable. On the basis of the 3 stability parameters (mean yield, linear regression, and deviation from regression), 2 genotypes were unstable with these criteria, namely G11, and G5. The lines of G2, G3, G4, and G16 had regression coefficients above 1 followed by high mean for pod yield indicates these genotype were below average stability, and adapt in favorable environment (Table 9). G8 and G16 identified as stable by the AMMI biplot also were by the Eberhart and Russell (1966) methodology. Genotype x environment interaction is described by biplot AMMI 2, show that G3 and G4 were adapt in environment E1 and E5 (productive environment), while G16 relatively stable to environmental changes (Figure 2).

DISCUSSION

Soil analysis on 8 environments indicates that the soil conditions were slightly to acid with a soil pH ranging between 4.5-6.4, and relatively low soil fertility. Some locations had Fe and Mn contents that were high to very high, and Al content which was low to high (Table 1). Environment E5 is the most productive environment (average yield 3.36 t ha^{-1}), while E4 was the most unproductive environment (average yield 1.37 t ha^{-1}), indicated by differences in the contents of Al, Fe, and Mn. These 3 elements are commonly found in acid soils and were reported to inhibit plant growth and caused the low yield (Shamsi *et al*., 2007; Panda *et al*., 2009; Millaleo *et al*., 2010).

Table 8. Stability of variance for pods yield of peanut genotypes at 8 environment trial on acidic dry soils in Lampung.

No	Source of Variation	df	Mean Square
	Genotype (G)	19	4.84
	Environnent (E) (E+(G x E)	140	54.4
	Environments (linear)	1	44.13
	Genotype x Environment (linear)	19	44.96
	Pool deviations	120	6.73
G1	MHS/91278-99-C-180-13-5	6	0.20
G2	G/92088//92088-02-B-2-9	6	0.52
G3	G/92088//92088-02-B-2-8-1	6	0.22
G4	G/92088//92088-02-B-2-8-2	6	0.65
G5	J/J11-99-D-6210	6	0.89 **
G6	P 9801-25-2	6	0.37
G7	G/92088/92088-02-B-8	6	0.19
G8	MHS/91278-99-C-174-7-3	6	0.34
G9	Jerapah	6	0.10
G10	J/91283-99-C-192-17	6	0.24
G11	MHS/91278-99-C-180-13-7	6	-0.00
G12	M/92088-02-B-1-2	6	0.48**
G13	MLG 7720	6	0.41
G14	MLG 7638	6	0.47
G15	GH02/G-2000-B653-54-28	6	0.04
G16	IC87123/86680-93-B-75-55-1	6	0.04
G17	IC87123/86680-93-B-75-55-2	6	0.41
G18	MLG 7932	6	0.51
G19	Unila 2	6	0.43
G20	Talam 1	6	0.21
	Pooled error	304	0.04

Table 9. Stability of pod yield of peanut genotypes.

No	Genotype	Code	Average yield (t/ha)	b_i	R	r	$Sd^2{}_i$	Remarks
1	MHS/91278-99-C-180-13-5	G1	2.40	1.08	0.90	0.95	0.03	S
2	G/92088/92088-02-B-2-9	G2	2.31	1.34	0.86	0.93	0.09	S
3	G/92088/92088-02-B-2-8-1	G3	2.47	1.27	0.91	0.95	0.04	S
4	G/92088/92088-02-B-2-8-2	G4	2.62	1.25	0.81	0.90	0.11	S
5	J/J11-99-D-6210	G5	2.26	1.15	0.75	0.86	0.15**	NS
6	P 9801-25-2	G6	2.43	1.03	0.83	0.91	0.06	S
7	G/92088/92088-02-B-8	G7	2.07	0.93	0.88	0.93	0.03	S
8	MHS/91278-99-C-174-7-3	G8	2.18	0.86	0.79	0.89	0.06	S
9	Jerapah	G9	1.94	0.72	0.88	0.94	0.02	S
10	J/91283-99-C-192-17	G10	2.25	0.77	0.81	0.90	0.04	S
11	MHS/91278-99-C-180-13-7	G11	2.16	0.70**	0.95	0.97	-0.00	NS
12	M/92088-02-B-1-2	G12	2.35	1.05	0.81	0.89	0.08	S
13	MLG 7720	G13	2.02	0.66	0.67	0.82	0.07	S
14	MLG 7638	G14	2.45	1.02	0.80	0.89	0.08	S
15	GH02/G-2000-B653-54-28	G15	2.15	0.90	0.94	0.97	0.01	S
16	IC87123/86680-93-B-75-55-1	G16	2.44	1.21	0.95	0.97	0.01	S
17	IC87123/86680-93-B-75-55-2	G17	2.50	1.08	0.83	0.91	0.07	S
18	MLG 7932	G18	2.19	1.04	0.80	0.89	0.09	S
19	Unila 2	G19	2.14	1.03	0.82	0.90	0.07	S
20	Talam 1	G20	2.13	0.85	0.85	0.92	0.04	
	Average		2.27	1.01	0.84	0.91	0.05	

The analysis of variance indicated a significant effect of the environment and G x E interaction. Most of the existing variance (92.1%) is explained by environment and interaction effect, which makes selection more difficult. Criteria for the stability of Eberhart and Russell (1966) was widely used to assist plant breeders to overcome the difficulties that rising from the existence of genotype x environment interaction.

Peanut genotypes have a different responses in each environment on acid soil Lampung, there were 9 genotypes that had pod yields above the general mean. Genotypes G16 have broad adaptability and relatively stable to environmental changes. Two genotypes, G3 and G4 were resistant to rust disease and have stability below average, which indicates that these genotypes adapt to productive environment. Kasno *et al*. (2013) reported that these 2 genotypes were also tolerant to acid soils as indicated by the highest Stress Tolerance Index (STI) on dry acid soil in Jasinga (Bogor, West Java).

The interaction between genotypes and environment for peanut yield were found in many other studies (Kasno *et al*., 2010; Nawaz *et al.,* 2009; Mothilal *et al.,* 2010; Kabede and Tana, 2014). The existence of genotype x environment interaction on 20 peanut genotypes was reported by Kasno *et al*. (2007) on Alfisol soils in East Java, Central Java, and entisol soils in Lampung. Another research shows that pod yield of peanut varieties Jerapah and Singa on tidal swams in Batola (South Kalimantan, pH 3.56, Al dd 5.5 me/100g) each of 1.52 t ha^{-1} and 0.80 t ha^{-1}, while in shallow swampy areas Pandawan-Hulu Sungai Tengah (Central Kalimantan, pH 4.8, Al dd 0.55 me/100g) each reached 2.71 t ha^{-1} and 3.21 t ha^{-1} respectively (Koesrini *et al*., 2006). The average yield of 50 peanut genotypes in Jasinga (Bogor-West Java, pH of 4.4 and 91.5 % Al saturation) of 1.27 t ha^{-1}, ranges from 0.55-2.21 t ha^{-1} (Trustinah *et al*., 2009).

Fikere, Tadese and Lettam (2008) at arabic bean (*Ficia faba*) found that all the stability parameter [(regression coefficient (bi), deviation of the regression (S^2di), coefficient Wrike (W^2i), stability variance (∂^2i), and stability of variance environmental (S^2i)} used were closely correlated, and concluded that all the parameters could be useful to assess the stability of the yield of an arabic faba bean genotypes.

Stability and adaptability had close relationships, if genotype environment interaction was caused by environmental factors that cannot be predicted, such as temperature, solar radiation, and precipitation of the environmental factors that can be predicted such as soil type and elevation (Finlay Wilkinson, 1963). Effects of the environment can be predicted, such as the type of climate, soil type, length of day, method of cultivation, crop density, harvesting, and other agronomic practice. while environmental factors that cannot be predicted among others such as climate change, and rainfall, temperature, solar radiation, and agronomic practices on farms that have not been developed (Allard and Bradshaw, 1964). Diversity of environments that can be predicted if the difference is large between environments such as the ocean climate and continental climate. Interaction of genotype and treatment (planting time, density, etc.) indicates that the treatment has made a special environment, so that the varieties developed that are adapted to the specific environment.

In this study, the interaction of genotype and environment caused by the differences in tolerance to leaf diseases, and differences in soil fertility. These factors could be predicted, because the disease usually attacked the leaves of peanut plants during the dry season, and the soil fertility could be determined by laboratory analysis. In general in acid dry land areas, peanut is planted early at the beginning of the rainy season.

CONCLUSION

The following findings can be summarized from this study: (1) genotype G16 was found to be the most stable genotype to environmental changes and have broad adaptability; and (2) genotypes G3 and G4 have specificity of adaptability to high-yielding environments.

REFERENCES

Acikgoz E, Ustus A, Gul I, Anlarsal E, Tekeli AS, Nizam I, Avcioglu R, Geren H, Cakmakci S, Aydinoglu B, Yucel C, Avci M, Acar Z, Ayan I, Uzun A, Bilgili U, Sincik M, Yavuz M. (2009). Genotype x environment interaction and stability analysis for dry matter and seed yield in field pea (*Pisum sativum* L.). *Spanish J. Agric. Res.* 7(1):96-106.

Allard RW, Bradshaw AD (1964). Implications of genotype-environmental interactions in applied plant breeding. *Crop Sci.* 4:503-508.

Das S, Misra RC, Patnaik MC, Das SR. (2010). G x E interaction, adaptability and yield stability of mid-early rice genotypes. *Indian J. Agric. Res.* 44(2):104-110.

Eberhart SA, Russell WA (1966). Stability parameters for comparing varieties. *Crop Sci.* 6:36-40.

Escobar M, Berti M, Matus I, Tapia M, Johnson B. (2011). Genotype x environment interaction in canola (*Brassica napus* L.) seed yield in Chile. *Chilean J. Agric. Res*. 71(2):175-186.

Fikere M, Tadesse T, Tesfaye Letta T (2008). Genotype-environment interactions and stability parameters for grain yield of Faba bean (*Vacia faba* L.) genotypes grown in South Eastern Ethiopia. *Int. J. Sustain. Crop Prod*. 3(6):80-87.

Finlay WK, Wilkinson GN. (1963). The analysis of adaptation in plant breeding programme. *Aust. J. Agr. Res.* 14:742-754.

Gauch HG. (2006). Statistical analysis of yield trials by AMMI and GGE. *Crop Sci*. 46:1488-1500.

Gurmu F, Mohammed H, Alemaw G. (2009). Genotype x environment interaction and stability of soybean for grain yield and nutrition quality. *African Crop Sci. J*. 17(2):87-99.

Kabede A, Tana T. (2014). Genotype by environment interaction and stability of pod yield of elite breeding lines of groundnut (*Arachis hypogaea* L,) in Eastern Ethiopia. *Sci. Technol. Arsts Res. J*. April-June 3(2):43-46.

Kasno A (2006). Prospect of development varieties of peanut to acid dry soil and tidal swarm. *Bulletin Crops* 11:1-6.

Kasno A, Trustinah, Purnomo J, Suwarsono B. (2007). Genotype-environment interactions and its implications in the selection of peanut promising lines. *J. Food Crop Res.* 26(3):167-173.

Kasno A (2010). Talam 1, peanut varieties adaptive dry acid soil and tolerant to *Aspergillus flavus*. *Bulletin Crops* 19:19-26.

Kasno A, Taufiq A, Trustinah (2013). Tolerance of peanut genotypes to acid soil condition. *Agrivita J. of Agric. Sci*. 35(2):145-159.

Koesrini, Noor A, Sumanto (2006). Yield performance of peanuts promising lines in acid sulfat soil and shallow swamphy. *Bul. Agron*. 34(1):11-18.

Mekontchou T, Ngueguim M, Fobasso M. (2006). Stability analysis for yield and yield components of selected peanut breeding lines (*Arachis hypogaea* L.) in the North Province of Cameroon. *Tripiculture* 24(2):90-94.

Millaleo R, Reyes-Diaz M, Ivanov AG, Mora ML, Alberdi M. (2010). Manganese as essential and toxic element for plants: transport, accumulation and resistance mechanisms. *J. Soil Sci. Plant Nutr.* 10 (4): 476-494.

Mothilal A, Vindhiya Varman P, Manivannan N. (2010). Stability analysis of foliar disease resistant groundnut genotypes (*Arachis hypogaea* L.). *Electronic J. Plant Breed*. 1(4):1021-1023.

Mulyani A, Rachman A, Dairah A. (2009). The spread of acid soil, potential and its availability for agricultural development. In: Sastramiharja M, Manalu MF, and Aprillani SE, eds., Natural phosphate: utilization of natural phosphate are used directly as a source of fertilizer P. Soil Research Centers, Bogor, Indonesia, pp. 25-46.

Namorato H, Miranda GV, Vago de Sauze L, Oliveira LR, Olievira deLima R, Mantovani ED. (2009). Comparing biplot multivariate analysis with Eberhart and Russell's method for genotype x environment interaction. *Crop Breed. and Applied Biotechnology* 9:299-307.

Nawaz MS, Nawaz N, Yousuf M, Khan MA, Mirza MY, Mohmand AS, Sher MA, Asif Masood M. (2009). Stability performance for pod yield in groundnut. *Pakistan J. Agric. Res.* 22(3-4):116-119.

Oliveira EJ, Godoy IJ. (2006). Pod yield stability of runner peanut lines using AMMI. *Crop Breed and Applied Technology* 6: 310-317.

Panda SK, Baluska F, Matsumoto H. (2009). Aluminium stress signaling in plants. *Plant Signaling & Behavior* 4(7):592-597.

Shamsi IH, Wei K, Jilani G, Zhang G. (2007). Interaction of cadmium and aluminium toxicity in their effect on growth and physiological parameter in soybean. *J. Zheijiang Univ. Sci. B* 8(3):181-188.

Statistics Indonesia. (2015). Statistical Yearbook of Indonesia 2015, BPS Catalog: 1101001. BPS-Statistics Indonesia. Jakarta.

Subrahmanyam P (1985) Screening methods and source of resistance to rust and leaf spot of peanut, CRISAT, India, pp. 7.

Taufiq A, Kuntiastuti H, Sudaryono (2004). Soil fertility levels in Central Lampung and Tulang Bawang. In: Makarim AK, *et al*. eds., Proc. Research for Legume and Tubers 2004. Research Institute for Legume and Tuber Crops. Malang, Indonesia pp. 418-433.

Trustinah, Kasno A, Wijanarko A, Iswanto R, Kuswantoro H. (2008). Adaptation legumes genotypes on dry acid soil. In: Arif Harsono, *et al.*, eds., Proc. Research for Legume and Tubers 2008. Research Institute for Legume and Tuber Crops. Malang, Indonesia pp. 200-207.

Trustinah, A. Kasno, dan A. Wijanarko. 2009. Tolerance of legume crops to acidic dry soil. *J. Food Crop Res.* 8(3):183-191.

Trustinah, Kasno A, Purnomo J, Suwasono (2011). Yield of peanut genotypes in acid soil. In: Adie MM, *et al*. eds., Proc. Innovation Technology for Development of Soybean towards Self-Sufficiency. Research Institute for Legume and Tuber Crops. Malang, Indonesia pp. 450-459.

Yan W, Kang MS, Ma B, Woods S, Cornelius PL. (2007). GGE Biplot vs. AMMI analysis of genotype-by-environment data. *Crop. Sci.* 47:643–655.

Zobel RW, Wright MJ, Gauch HG. (1988). Statistical analysis of a yield trial. *Agron. J.* 80:388-393.