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STABILITY AND ADAPTABILITY OF NINE OPEN POLLINATED VARIETIES OF UB MAIZE

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ABSTRACT

Open pollinated maize and two check varieties were evaluated in four locations, i.e. Malang, Jombang, Kediri, and Trenggalek regencies for two seasons from March to November 2009. The research objective was to determine stability and adaptability of the open pollinated maize. The experiment was conducted using a randomized complete block design. The treatment had nine lines, i.e. UB4101, UB3101, UB4201, UB7201, UB4202, UB3301, UB4301, UB7301, UB3302 and two check varieties, Bisma and Arjuna. The treatment was repeated three times. Percentage point of variance ratio was applied to determine homogeneity error. Variance analysis of combined experiment was conducted to determine genotype x environment interaction. Yield stability and adaptability were analyzed using Eberhart and Russell linear models. There was genotype x season x location interactions on maize yield. It mean that there were population yield performance changes at different environments. There were four populations have stability point, i.e. UB4101 (5.5 t ha^{-1}), UB3301 (5.7 t ha^{-1}), UB7301 (5.7 t ha^{-1}), and UB3302 (5.4 t ha^{-1}). Population UB4201 (5.1 t ha^{-1}) was adaptable to productive environment, and UB4301 (5.8 t ha^{-1}) was adaptable to marginal ones.

Keywords: G × E interaction, stability, adaptation, open pollinated maize variety, UB line

INTRODUCTION

Maize is a national strategic commodity. In 2005-2009 the national maize production increased 9.95 percent per year, productivity rose 4.78 percent, and level of maize consumption also increased 21 percent. Supplies of maize in Indonesia include 0.5 percent for the seed, 29 percent for feed and 6.3 percent for daily consumption, 11.3 percent of the runoff and shrinkage, and 52.9 percent for industrial needs and other processed food (Secretariat Republic of Indonesia, 2010).

Open pollinated varieties have the opportunity to develop broadly and reduce farmers' dependence on costly hybrid maize. Hybrid seeds that are generally sold with a relatively high price should be planted in a productive environment, and its seed cannot be used as a seed anymore. While open pollinated, seed price is relatively cheap. It can grow on changeable environments and the yields are close to the average environment, and the harvested grain can be used as a seed. In effort to provide high-yield varieties, the Laboratory of Plant Breeding has developed UB open pollinated maize.

Development of open pollinated cultivars needs to consider the environmental impact to study the response of plants on environmental changes. The existence of genotype x environment interaction may cause inconsistent yields at different environments. Vargas *et al.* (2001) and Campell and Jones (2005) suggested that interactions of genotype x environment is a differential response of genotypes to environmental changes. Fluctuations in these yields are related to the genetic potential of plant in response to environmental changes (Baihaki and Wicaksana, 2005; Waluyo *et al.*, 2006). Genotype evaluation in multi-location is important to know the adaptability, yield potential and stability. The genotype which have broad and narrow adaptation can be determined. According to Yan and Hunt (2001), an understanding of the causes of genotype x environment interaction can be used to establish breeding objectives, identify ideal test conditions and to formulate recommendations for local adaptation.

Bilbro and Ray (1976) suggested that the breeding program's success will be achieved if the following aspects are considered (i) the level of the genotype, i.e. the average yields compared with the control genotype, (ii) adaptation, which forms an environment that can bring the best genotypes-genotypes, and (iii) stability, i.e. the consistency of the yields of a genotype compared with other genotypes. All these aspects will be integrated in a single measurement yield of a genotype. In this regard, genotype testing is necessary to obtain information about genotype x environment interaction, stability and adaptability of nine open pollinated maize genotypes UB in several different locations and seasons. Some genotypes can be selected and recommended as a potential candidate for high yield varieties. Some varieties have a stability and high yield is needed by farmers having small plots of land to reduce risk of crop failure due to unpredicted changes in environmental factors.

MATERIALS AND METHODS

The field trials were conducted in 4 (four) locations in East Java, namely Jatikerto (Malang, altitude: 330 m above sea level, rainfed, Alfisol soil type, temperature: 27^{o}C, 147 mm rainfall per month), Pare (Kediri, altitude: 200 m above sea level, Entisol soil type, average temperature: 29^{o}C and 141 mm rainfall per month), Jombang (Jombang, altitude: 44 m above sea level, rainfed, Vertisol soil type, temperature 27^{o}C and the average rainfall is 123 mm per month) and Gandusari (Trenggalek, altitude: 120 m above sea level, rainfed, Vertisol soil type, average temperature: 29^{o}C and 165 mm rainfall per month). The first planting was conducted at the end of the rainy season 2008/2009, and the second planting was done during the planting season in 2009.

Materials used in this study were nine open pollinated maize genotypes, namely UB4101, UB3101, UB4201, UB7201, UB4202, UB3301, UB4301, UB7301, UB3302, and two open pollinated maize varieties for comparison, namely Bisma and Arjuna, Urea and NPK compound fertilizers. UB genotypes have been developed in the Laboratory of Plant Breeding, Faculty of Agriculture, since 1999 (Waluyo *et al*., 2000; Basuki *et al*., 2001).

At each research location, open pollinated maize genotypes were arranged in a randomized block design (RBD) with three replications. The genotypes were planted in a 3 x 5 m plot consisting of four rows. Each row consisted of 25 plants, so that each plot consisted of 100 plants. Urea, SP-36 and KCl fertilizers were applied at rates of 250 kg ha^{-1}, SP-36 100 kg ha^{-1}, and KCl 100 kg ha^{-1}, respectively. Observation of the conversion yield of seed dry weight (15%) was made in the middle of two rows of the plot (Subandi *et al.*, 1982).

Analysis of variance was performed at each location to assess the differences in response of each population against the location and season and to value the error variance.

Homogeneity of variance test error for all environments was performed using a percentage point the maximum variance ratio and the smallest variance (Petersen, 1994). As recommended by LeClerg *et al.* (1962) and Steel and Torrie (1981) the error variance homogeneity test is needed if the research is to be conducted in more than one location. If the error variance is homogeneous, the test is continued with the analysis of variance combined in some locations and seasons according to McIntosh (1983) with a fixed population model, seasonal and location random. The average difference among populations was tested by using Duncan Multiple Range Test 5%. If the results of the combined analysis of variance for all of the real environment show significant differences, further analysis of stability and adaptation of the results was performed to determine the populations which have a wide adaptability or adapted to specific environmental areas.

Table 1. Combined analysis of variance in two or more location and seasons

Source	df	Mean square	F stat
Seasons	y-1	MS1	MS1/MS3
Locations	l-1	MS2	MS2/MS3
Seasons x locations	(y-1)(l-1)	MS3	MS3/MS4
Replication (seasons x locations)	yl(r-1)	MS4	
Genotypes	g-1	MS5	(MS5+MS8)/(MS6+MS7)
Genotypes x seasons	(g-1)(y-1)	MS6	MS6/MS8
Genotypes x locations	(g-1)(l-1)	MS7	MS7/MS8
Genotypes x seasons x location	(g-1)(y-1)(l-1)	MS8	MS8/MS9
Error	yl(r-1)(t-1)	MS9	
Total	rt-1	MS Total	

Remarks = y= season, l = location, r = replication, g = genotypes, KT = mean square

Yield stability was analyzed using a linear model of Eberhart and Russell (1966): $Y_{ij} = \mu_i + \beta_i I_j + \delta_{ij}$, where Y_{ij} = mean of genotypes i-th in environment j-th, μ = mean all genotype in all environment, β_i = regression coefficient of genotype i-th in environmental index indicating the genotype of the variation of environmental response, $I_j = \left(\frac{\sum_i Y_{ij}}{v}\right) - \left(\frac{\sum_i \sum_j Y_{ij}}{vn}\right)$= environmental index, i.e. the average deviation from the genotype in an environment of all average, δ_{ij} = deviation from means square of genotype i-th in environment j-th, v = numbers of genotypes, n = numbers of environment.

A genotype has stable appearance if the value of regression coefficient $\left(b = \frac{\sum_j Y_{ij} I_i}{\sum_j I_j^2}\right)$ is not significantly different from one and the deviation $\left(\bar{S}d^2 = \frac{\sum_j \hat{\delta}_{ij}^2}{n-2} - \frac{S_e^2}{r}\right)$ is not significantly different from zero.

Adaptation of the genotypes is determined according to Finlay and Wilkinson (1963). If the value of deviation of genotypes is equal to zero and has a value of b>1, then the population is responsive to the productive environment so that these populations are adaptable to a productive environment. If a population has a value of b <1, then the population is less responsive to environmental changes so that these populations are adaptable to a non productive environment. Analysis of variance was performed using the software DAASTAT (Onofri, 2006), means different test of Duncan's multiple range test was analyzed using SASM-Agri (Althaus *et al.*, 2001), and the adaptation and yield stability analysis were analyzed using CropStat 2.7 for Windows (Crop Research Informatics Laboratory, 2007) .

RESULTS AND DISCUSSION

Analysis of Variance

Analysis of variance on the yield of maize indicated that dry grain yield of open pollinated genotypes varied according to location and season (Table 2). It showed that there were genotypes showing high yield at each location and each season, and genetic factors influence the difference in each genotype. However, the differences that occur in genotype are still biased because of the treatment being tested. There are still some elements included such as location, season, and interaction components of the season, location and genetic (Fehr, 1987). Influence of each element can be eliminated by the combined analysis of variance.

Based on the results of homogeneity test error range (Table 2), the error variance ratio of the value of the maximum and minimum error variance was smaller than the value of percentage point error variance ratio of maximum and minimum error variance at level 5% with the db (8, 20). This indicates that the error resulting from the research at each location and season is homogeneous. Thus the combined analysis can be done using the same error.

Combined analysis (Table 3) showed that there were genotypes x season interaction effects on the performance of the genotype x location interaction. The interaction of season and genotype x location also played a role in the diversity of maize genotype appearance. Interaction of season x location of the real environment showed that the average of all maize genotypes had relatively better performance in a single season than in other seasons. Because the differences in genotype performance were not part of this comparison, this interaction had no relation to the recommendations related to the appearance of genotype. Thus, comparison of the location and the season was just to show the yield performance of different genotypes in different locations in consecutive seasons.

Genotypes showing significant differences in appearance were caused by differences in genetic potential of maize tested. This gives the opportunity to select a genotype having high yield. Interaction of genotypes x seasons x locations showed that the genotypes x seasons interaction was different at different locations. Since the value of the variance for varieties significantly exceeded the variance of genotype x location and genotype x season variance, then the general recommendation can be made to determine the maize genotypes adaptable to specific environments, and the recommendation of genotypes adaptable to all environments. This means there is a harvest fluctuation of maize genotypes in different locations and seasons, and there is a stable performance in all environments. This fluctuation was caused by the accumulation of genetic background influenced by the genotype, planting season, and location.

Table 2. Mean square and homogeneity of error variance test based on percentage of point maximum variance and minimum variance

Environment	Mean squares of treatment	Means squares of error
Jombang MH 2008/2009	0.97*	0.25
Jombang MK 2009	1.29*	0.19
Kediri MH 2008/2009	0.68*	0.21
Kediri MT2 MK 2009	1.51*	0.20
Malang MH 2008/2009	0.73*	0.42
Malang MK 2009	1.52*	0.40
Trenggalek MH 2008/2009	0.60*	0.49
Trenggalek MK 2009	1.06*	0.36
Max. Var. / min. Var.		2.6ns
Table value5 % for percentage of point maximum variance and minimum variance (Petersen, 1994)		4.1

Remarks = * significant, ns: non-significant

Table 3. Combined analysis of variance in two or more locations and years

Source	df	Mean square	Fstat	ProbF
Seasons	1	107.09	3.86	0.1441
Locations	3	59.13	2.13	0.2749
Seasons x locations	3	27.72	42.68	0.0000**
Replication (seasons x locations)	16	0.65		
Genotypes	10	2.73	2.04	0.0473*
Genotypes x seasons	10	0.90	1.17	0.3494
Genotypes x locations	30	0.81	1.04	0.4524
Genotypes x seasons x locations	30	0.77	2.45	0.0002**
Error	160	0.32		
Total	263	1.95		
CV = 10.6%				

Remarks = *significant at F5%, ** significant at F1%, df = degree of freedom

According to Allard and Bradshaw (1964), the fluctuation caused by differences in the composition of the genes was possessed by each genotype. Genotypes having a broad genetic makeup or genotype buffer have strong individual ability to resist the influence of environmental changes on the wide range of environments. On the other hand, those having a narrow genetic makeup will have a low buffer genotype or individuals that can easily be influenced by environment. As proposed by Geiger and Servaites (1991), plant response to environmental changes can be described as a modification of organs and redistribution of photosynthates between the biochemical pathways that enables plants to keep utilizing the potential of the environment optimally. Interwoven cues and response mechanisms are genetically complex and varied in levels of efficiency in the utilization of these environments, and they have a different mechanism in each genotype. Kang (1998) suggested that genotype x environment interaction occur because of (1) environmental stress on the genome, (2) the biotic stress that causes long-term induction and has a broad spectrum such as systemic resistance (SAR), superoxide dismutases (SOD) or associated with catalases performances in different environments, (3) the biochemical mechanisms of plant diversity in response to environmental stress as biological, chemical, and physically shown by the decrease of photosynthesis, biomass, and growth, and (4) the high level of phenotypic flexibility of the plant environment experience fluctuations.

With the existence of genotype x environment interaction, a genotype that displays the highest yield at a given location is often not consistent in other locations. It is difficult for breeders to select the best strain (Samaullah and Moentono, 1996). Baihaki *et al.* (1976) argued that the magnitude of genotype x environment interactions needs to be considered to avoid loss of potential genotypes. Therefore, the testing of a strain in several different environments needs to be done to obtain more comprehensive information mainly about the diversity that comes under the influence of different external conditions. Waluyo *et al.* (2006) who tested the genotype x environment interaction on maize at five locations i.e., Blitar, Malang, Kediri, Jember and Probolinggo, indicated that some maize genotypes showed yield fluctuations beside the appearance of other genotypes that was relatively stable in some locations. Thus, the yields of maize will always be influenced by the environment.

Yield Stability and Adaptability

In this study, the genetic composition of genotypes in a population is heterozygous-heterogeneous and phenotypical is almost uniform. This study shows the effect of the interaction season x genotype x location (Table 4). Table 4 shows that the variations of maize genotype performance ware influenced by genetic factors, locations, seasons, and the interaction of all factors. Because there was interaction between season and environmental location, the combination of interaction is divided into eight units and each genotype can be assessed in the range of yield stability and environmental adaptability. Annicchiarico (2002) suggested that the environment is the accumulation of all the elements of climate, soil, biotic factors, and cultivation conditions in a location and season. Environment can also be connected to the cultivation system. The environmental review is not specifically elucidated by breeders but rather by how the genetic response of all the elements influences plant growth. The consequences of genotype x environment interaction are the existence of different responses of each genotype at different locations and seasons. In this experiment, elements of climate, soil type, average temperature, altitude and rainfall showed a variation.

In Jombang planting season 1, all tested genotypes (UB4101, UB3101, UB4201, UB7201, UB4202, UB 3301, UB 4301, UB7301 and UB 3302) had the same appearance with that of Bisma variety, and the performance of UB3101, UB4201, UB7201, UB4202 and UB7301 genotypes were similar to Arjuna variety. In Jombang planting season 2, eight genotypes (UB4101, UB3101, UB4201, UB 4202, UB7201, UB 4301, UB7301 and UB 3302) looked similar to Bisma and seven genotypes (UB4101, UB3101, UB4201, UB7201, UB4202, UB 4301 and UB 3302) looked similar to Arjuna. Genotypes that resulted in highest yields in Jombang planting season 1 and planting season 2 were UB3301 and UB7301 (Table 4). In Kediri planting season 1 there were eight genotypes (UB4101, UB3101, UB4201, UB 4202, UB7201, UB 4301, UB7301 and UB 3302) that looked similar to Bisma, and there were eight genotypes (UB4101, UB3101, UB4201, UB 4202, UB7201, UB 4301, UB7301 and UB 3302) that looked similar to Arjuna. In Kediri planting season 2, seven genotypes (UB3101, UB4201, UB7201, UB4202, UB 3301, UB 4301 and UB 3302) looked similar to Bisma, and eight genotypes (UB3101, UB4201, UB7201, UB4202, UB 3301, UB 4301, UB7301 and UB 3302) looked similar to Arjuna. Considering the yield performance in Kediri planting season 1 and planting season 2, there were four superior genotypes, namely UB4101, UB4301, UB7301 and UB3302 (Table 4).

In Malang planting season 1 and planting season 2, there were eight genotypes (UB4101, UB3101, UB4201, UB7201, UB4202, UB 4301, UB7301 and UB 3302) having similar appearances to Bisma and Arjuna. Based on the yield rank, there were only four genotypes showing high yields, i.e. UB4101, UB4301, UB7301 and UB3302 (Table 4).

In Trenggalek planting season 1, there were seven genotypes (UB4101, UB4201, UB7201, UB4202, UB 3301, UB7301 and UB 3302) that looked similar to Bisma, and all nine genotypes (UB4101, UB3101, UB4201, UB7201, UB4202, UB 3301, UB 4301, UB7301 and UB 3302) looked similar to Arjuna. In Trenggalek planting season 2, all nine genotypes looked similar to Arjuna and Bisma varieties. Based on the change of the genotype rating, there were four physiologically excellent genotypes at the planting season 1 and planting season2, i.e. UB4101, UB7201, UB4301 and UB7301 (Table 4). The existence of genotype rank changes compared with the check varieties, and the change in average rank of the genotypes showed the existence of environmental influences that changed the appearance of maize genotypes. Waluyo *et al.* (2006) also found changes in ratings on hybrid maize grown in several locations.

Based on the analysis of yield stability of Eberhart and Russell (1966) and Finlay and Wilkinson (1963), this study gained seven genotypes UB and two varieties that can adapt to all locations and at different planting seasons, and two of the seven genotypes adapted to specific environmental (Table 4). In addition to adapting to a broad or narrow adapted genotypes selected, the genotypes must also have appearance of yields above common average and have an average yield equal to or higher than the check varieties.

Genotypes having stable appearance, ability to adapt to a wider environment, and high yield were UB4101 (5.5 t ha^{-1}), UB3301 (5.7 t ha^{-1}), UB7301 (5.7 t ha^{-1}) and UB3302 (5.4 t ha^{-1}). Each of these genotypes had a regression coefficient equal to one and the deviation of the regression was zero, and the yield performance was higher than the general average. Such genotypes would have the appearance of conformity with environmental productivity.

UB4201 (5.1 t ha^{-1}) have a lower yield average than the general average and adapted to the productive environments. This genotype also showed similar yield to the check varieties. This genotype had a regression coefficient value above one and deviation of regression was zero. Such a genotype is very responsive to environmental changes with high input. UB4301 (5.8 t ha^{-1}) was adapted to marginal environments. This genotype had a regression coefficient value below one and the deviation of the regression was zero. Appearance of this genoype was usually below average and not responsive to environmental changes. Utilization of broadly adapted genotypes where the approach to improving yields in farming can be done with the cultivation techniques that are commonly practiced by farmers. If genotyping for productive environment is carried out by intensive cultivation, the yield obtained would be very high, but this practice will burden small holder farmers while the adaptive genotypes in the marginal environment may be cultivated with low input farming systems. Testing on a wider range of locations and different seasons is necessary to elucidate the more representative stability and adaptability.

Results of interpretation of the environmental index showed that Jombang in the first planting season had an unproductive environment, the environmental index -2.1 and the second planting season to be somewhat productive cropping environment with an index of 0.3 (Table 4). Unproductive environment occurred because the land use is rainfed. Although the first planting was conducted in the rainy season, there was no rain during early plant growth, so the plants experienced drought stress.

Table 4. Performance yield stability and adaptability (t ha^{-1}) across environment

Genotypes	Jombang		Kediri		Malang		Trenggalek		Yield Means (t ha^{-1})	b_i	sdi^2
	PT1	PT2	PT1	PT2	PT1	PT2	PT1	PT2			
UB4101	2.4c	5.0c	5.0abc	6.5a	5.5abc	7.8bcd	5.9a	5.5abc	5.5	1.1	0.4
UB3101	3.1abc	5.2c	4.8bc	5.2bcde	5.3abc	6.9d	4.7b	4.3d	4.9	0.8	0.0
UB4201	2.7bc	5.5bc	4.6c	4.4e	4.6c	9.2a	5.3ab	4.6cd	5.1	1.4*	0.2
UB7201	2.8bc	4.9c	4.3c	4.3e	5.2bc	6.9d	5.1ab	5.7ab	4.9	0.9	0.1
UB4202	2.7bc	5.4bc	5.0abc	4.9cde	5.8ab	7.6cd	5.1ab	4.4d	5.1	1.0	0.0
UB3301	4.0a	7.1a	5.9a	4.5de	6.3a	7.7cd	5.1ab	4.8bcd	5.7	0.8	0.6
UB4301	4.0a	5.8bc	5.7ab	5.5abcd	6.0ab	7.8bcd	5.8a	6.2a	5.8	0.8*	-0.1
UB7301	3.5abc	6.4ab	5.0abc	6.2ab	5.2bc	8.7ab	5.2ab	5.5abc	5.7	1.2	0.1
UB3302	3.7ab	5.3c	5.0abc	5.7abc	5.6abc	8.0bc	4.5b	5.6abc	5.4	0.9	0.1
Bisma	3.2abc	5.4bc	4.7bc	4.6cde	5.3bc	8.0bcd	4.6b	5.2abcd	5.1	1.1	0.0
Arjuna	2.6c	5.1c	4.4c	5.2bcde	4.9bc	7.2cd	4.9ab	5.4abcd	5.0	1.0	0.0
Means of environment	3.2	5.6	4.9	5.2	5.4	7.8	5.1	5.2	5.3		
Environmental index	-2.1	0.3	-0.3	-0.1	0.1	2.5	-0.2	-0.1			
Means of location	4.4	5.1	6.6	5.1							

Remarks = b = coefficient regression, Sdi^2 =deviation, numbers followed by same letter in a column are not significantly different in Duncan's multiple range test 5%, * significant different from 1 or 0, PT = planting season

Kediri and Trenggalek have a less productive environment in the first and second planting seasons. This is because of drought stress during the experiment. Malang has a productive environment compared to the three locations both in the first and second planting season (0.1 and 2.5). This is because of insufficient irrigation water for plants. Productive environment is characterized by the average value of the environment and high environmental index values. Less productive environment is characterized by the average value of the environment and lower environmental index value.

Although the genetic expression will be influenced by the environment, some plants can benefit the environment by converting an optimal yield that is shown by the low level of fluctuations in the environment at large. According to Allard and Bradshaw (1964), the stability of the yields is determined by the individual buffer and buffer genotype. The heterozygous individuals are more resistant to environmental fluctuations compared with the homozygous plants, and the heterozygous genotype-heterogeneous will have the resilience to environmental changes compared with the homogenous genotype. The mechanism of stability emerged through genetic heterogeneity, the compensation component of yield, tolerance to environmental stress, and rapid recovery of power against environmental stresses (Heinrich *et al.*, 1983).

CONCLUSIONS AND SUGGESTIONS

Yield performance of open pollinated maize UB is influenced by genetic factors, environmental and their interactions. There are genotypes that are broadly adapted to all environments and there are genotypes that are adapted to specific environments. Open pollinated maize genotypes that have higher yields than the check varieties, and that have high yield stability and wide adaptability, are namely UB4101 (5.5 t ha^{-1}), UB3301 (5.7 t ha^{-1}), UB7301 (5.7 t ha^{-1}), and UB3302 (5.4 t ha^{-1}). UB4201 (5.1 t ha^{-1}) adapted in productive environment, while UB4301 (5.8 t ha^{-1}) adapted in marginal environment.

According to the Regulation of the Minister of Agriculture No: 37/Permentan/OT.140/8/2006 about Testing, Assessment, Release and Withdrawal of Variety, the candidate varieties of maize that will be released as new varieties should be tested for adaptation at 16 units consisting of eight different locations during two seasons. Thus, the selected genotypes still require minimal testing at four locations during two seasons in order to fulfill the trial as the potential release of superior varieties of high yielding open pollinated maize UB.

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