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Research Article
Genotype×Environment Interaction of Maize Hybrids under Intercropping With Sweet Potato in Indonesia

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Abstract

Background and Objectives: Intercropping of maize with sweet potato is one of cropping systems to improve land use efficiency of maize and sweet potato. The goals of the research were to study G×E interaction and to select adaptive maize hybrid for intercropping with sweet potato. **Materials and Methods:** Two experiments were set up in Bandung, Indonesia during rainy and dry season. The genetic materials were 13 new and one commercial check hybrids. These materials were cultivated based on a split plot design arrangement with two replications which the main plot comprised maize sole cropping and maize/sweet potato inter-cropping and the sub-plot was the hybrid. Data analysis covered the analysis of variance of maize hybrid in the maize sole cropping and in the intercropping system with sweet potato during both rainy and dry seasons. Homogeneity of variance error was tested using Bartlett test. Combined ANOVA was pursued to determine the interaction of G×E interaction (GEI) when variance errors were homogenous. Adaptability of maize hybrids was determined using genotype and genotype-environment interaction (GGE) biplot analysis. **Results:** The adaptive maize for intercropping with sweet potato was selected based on their land equivalent ratio (LER) and competitive ratio (CR). Genotype 3×4 was selected as potential hybrid variety for intercropping with sweet potato. **Conclusion:** The G×E interaction (GEI) plays an important role for male flowering and yield as well as genotype in this study. Selection of stable and adaptive maize hybrid variety for intercropping with sweet potato requires further multi-environment evaluation in several locations in Indonesia.

Key words: Adaptability, GGE, G×E interaction, intercropping, maize hybrids, sweet potato

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Maize and sweet potato are 2 significant crops and plays a key role for present agro-industry in Indonesia. Corn starch and high fructose corn syrup are used for food industry, grain and hay for livestock and ethanol for fuel[1]. On the other hand, sweet potato is amongst the most important tuber used as substitute food staple included in the major daily diets of Indonesians. Sweet potato is important because of its carbohydrate and nutrient content such as β-carotene. They are also consumed for diverse agro-industrial raw materials, such as feed ingredients and bioethanol materials[2,3].

Intercropping can increase production of both maize and sweet potato in Indonesia. The system utilizes efficient nutrients, water and light, thus energizing sustainable agriculture. Many researchers had reported the advantages of intercropping which includes, (1) Increase the efficiency of land usages since they can utilize extra sunlight than by cultivating alone, (2) Use nutrient and water efficiently, (3) Improve ecological function, (4) Prolong the cultivating season, (5) Reduce the harvest risk due to biotic stress, soil deterioration and environmental degradation and (6) Lower carbon emission and soil respiration in arid land[4,5]. The system could be successfully implemented if high yield maize hybrids can be selected for intercropping.

Multi-environment test (MET) is an important stage in selecting superior maize hybrids under different cropping system and planting season for commercially released cultivars. The test is used to determine the genetic×environment interaction (GEI) and to select adaptive hybrids for particular environment or to select stable hybrid for wide environments[6]. Selection of high yield genotype under different environment and season was complex as indicated by unpredictability of its rank in different locations. Furthermore, crop evaluation during MET affects phenotypic stability of particular genotypes, in which the variations of the genotype in different environment occurs due to GEI[7,8]. Therefore, identification of causal factor(s) of the GEI is significant to adopt the breeding objectives, to decide the best location of crop evaluation and to select regional genotypes.

Genotype and genotype-environment interaction (GGE) biplot is commonly applied to study stability and adaptability of new varieties as well as GEI. The GGE biplot was developed to select and to identify stable and adaptive varieties under different environments[9]. The GGE biplot had been applied by many breeders to analyze the GEI in many crops including maize[6,10], sorghum[11], wheat[12] and chickpeas[13].

Ruswandi *et al.*[14] and Yuwariah *et al.*[15] reported the initiation of breeding programs for developing high yield and nutrient composition maize hybrid for intercropping in Indonesia. Some potential hybrids which have high yields and high nutrient compositions have been revealed[16,17]. However, the information on their performance in intercropping with sweet potato has not yet been explored. The goals of the research was to study the G×E interaction and to select adaptive hybrids in this system.

MATERIALS AND METHODS

Experimental site: The evaluation was conducted in Arjasari, West Java, Indonesia at 750 m above sea level (a.s.l.) with climate type C3 by Oldeman[18].

Materials and research tools: Fourteen new maize hybrids were used in the study (Table 1). These hybrids were developed by Plant Breeding and Seed Technology Laboratory, University of Padjadjaran, Bandung, Indonesia. These hybrids, derived from parental line containing high nutrition and yield and are also resistant against downy mildew[14]. In addition, Rancing, a commercial sweet potato cultivar was used in this evaluation since it was the best commercial sweet potato cultivar in West Java[19].

Research procedure and experimental design: Two experiments were set up in Arjasari-Bandung, West Java based on a split plot design with 2 replications in which cropping system as main plot and maize hybrids as sub-plot. The 1st experiment was set up during rainy season from December, 2016 up to March, 2017 and the 2nd one was during dry season from May, 2017 up to August, 2017. For the main plot, 2 sets of trials were conducted namely maize sole cropping and maize/sweet potato intercropping. In maize sole cropping, the genetic materials were laid on a randomized block design with 2 replications and were cultivated as 1 row plot, 5 m long and 25 cm spacing in row and 75 cm between rows. In intercropping, the maize hybrids were also set in a randomized block design with 2 replications and were planted in 2-row plot with sweet potato in a 1:1 ratio, 5 m long, 25 cm spacing in row and 75 cm between rows. The plant density of maize in sole cropping is equal to 66,667 plant ha^{-1}, whereas, in intercropping with sweet potato is equal to 33,334 plant ha^{-1}.

Data collection and parameters measured: The traits observed were male flowering (days after planting) and yield (t ha^{-1}) for maize and tuber yield (t ha^{-1}) for sweet potato.

Table 1: Pedigree of parental hybrid line

Genotype	Parental hybrid		Note
	Female	Male	
1×2	G1	DR 10×MDR 9.1.3	DR 10 is high protein inbred, MDR 9.1.3 is mutant line
1×4	G2	DR 10×DR 18	DR 18 is high protein inbred
1×6	G3	DR 10×DR 8	DR 8 derived from crossing downy mildew resistant line with high protein line
2×13	G4	MDR 9.1.3×MDR 1.1.3	MDR 9.1.3 is a mutant line derived from irradiation of DR 9 by gamma (γ) with the dosage of 200 Gy, whereas, MDR 1.13 is mutation of DR 1 by gamma with the dosage of 200 Gy
2×15	G5	MDR 9.1.3×G 203-1	G 203-1 is a white maize line from ICERI Maros
3×4	G6	MDR 7.4.1×DR 18	MDR 7.4.1 is a mutant line derived from irradiation of DR 7 by gamma (γ) with the dosage of 200 Gy
3×11	G7	MDR 7.4.1×MDR 18.8.1	MDR 18.8.1 is a mutant line derived from irradiation of DR 18 by gamma (γ) with the dosage of 200 Gy
3×13	G8	MDR 7.4.1×MDR 1.1.3	MDR 1.1.3 is mutation of DR 1 by gamma with the dosage of 200 Gy
6×7	G9	DR 8×MDR 3.1.4	MDR 3.1.4 is mutation of DR 3 by gamma with the dosage of 200 Gy
6×9	G10	DR 8×G 673	G 673 is yellow maize line from BALITSEREALIA
6×11	G11	DR 8×MDR 18.8.1	MDR 18.8.1 is a mutant line derived from irradiation of DR 18 by gamma (γ) with the dosage of 200 Gy
6×13	G12	DR 8×MDR 1.1.3	MDR 1.1.3 is mutation of DR 1 by gamma with the dosage of 200 Gy
11×12	G13	MDR 18.8.1×MDR 7.1.9	MDR 7.1.9 is a mutant line derived from irradiation of DR 7 by gamma (γ) with the dosage of 200 Gy
PERTIWI-2	G14	PTW-2	Commercial hybrids in Indonesia

Statistical analysis: Data analysis covered the evaluation of maize hybrid in a maize sole cropping (E1 and E3) and in an intercropping system with sweet potato (E2 and E4). The analysis of variance (ANOVA) for male flowering and yield followed that of Petersen[20]. Homogeneity of variants error for four environments was tested using Bartlett's test[20]. Combined ANOVA for the four environments was pursued to determine the GEI when variance errors were homogenous.

Adaptability of hybrids was determined using GGE biplot analysis. Linear model of a GGE biplot based on singular value decomposition (SVD) of t principal components was described as follows[18]:

$$\overline{Y}_{ij} - \mu_i - \beta_j = \sum_{k=1}^{t} \lambda_k \alpha_{ik} \gamma_{jk} \varepsilon_{ij}$$

where, Y_{ij} is the performance of genotype i in environment j, μ is the grand mean, β_j is the main effect of environment j, k is the number of PC, λ_k is singular value of the kth PCs and α_{ik} and γ_{jk} are the scores of ith genotype and jth environment, respectively for PCs k, ε_{ij} is the residual associated with genotype i in environment j. Combined ANOVA and GGE analysis as well as their biplots were computed using PB Tools software developed by International Rice Research Institute[21].

The adaptive maize hybrid performance in maize/sweet potato intercropping was selected based on Land Equivalent Ratio (LER)[21,14] and competitive ratio (CR)[22].

RESULTS

Genotype×environment interaction of maize hybrids: Mean for male flowering and yield of new Indonesian maize hybrids showed their broad range of variation under different cropping systems and years (Table 2). The earliest male flowering was in E3 (43.0 days after planting = dap); whereas, the longest male flowering was in E2 (65.0 dap). The highest grain yield was in E2 (11.4 t ha^{-1}), while the lowest grain yield was in E4 (3.8 t ha^{-1}).

The GEI plays an important role for male flowering and yield as well as genotype in this study (Table 3). From Table 3, it is shown that all hybrids express various responses in different cropping systems and seasons.

Adaptability of maize hybrids based on GGE biplot: Adaptability of maize hybrids based on GGE analysis is presented in Table 4 and 5, whereas, their mean was presented in Table 6. The GGE analysis revealed significant accumulation percentage of mean square for IPCA-1 and IPCA-2 as follows 39.5, 66.7, 46.7 and 70.1%, for male flowering and yield, respectively.

The GGE biplots for male flowering and grain yield were drawn using IPCA 1 and IPCA 2 values for both hybrids and cropping systems and planting seasons (Fig. 1, 2). The GGE biplot showed that hybrids G9, G6, G14, G7 and G11 were the uppermost from the starting point and performed a high response (+/-) with particular cropping system and planting seasons for male flowering (Fig. 1). Hybrids G14, G10, G12, G2 and G13 were found at the outermost from the starting point and showed a high response (+/-) with specific cropping system and seasons for grain yield (Fig. 2). A polygon was drawn by joining the outmost hybrids with lines. Lines upright to the edges of the polygon were connected and these shaped 4 sections of which only 2 showed environment undoubtedly appointed to a hybrid at the highpoint of the polygon for male flowering. The E2 (maize/sweet potato cropping system, rainy season 2017) was in sector 2 and the

Table 2: Mean, range and standard deviation of maize hybrids under different cropping system and years

	Male flowering (days after planting)			Grain yield (t ha^{-1})		
Cropping systems	Average	Range	Standard deviation	Average	Range	Standard deviation
Sole maize (2016) (E1)	56.7	54.50-59.0	1.4	8.38	6.4-10.5	1.3
Maize/sweet potato (2016) (E2)	61.5	60.00-65.0	1.3	8.45	6.3-11.4	1.4
Sole maize (2017) (E3)	46.6	43.00-51.5	2.6	6.48	5.4-7.3	0.5
Maize/sweet potato (2017) (E4)	48.6	45.00-50.5	1.5	5.83	3.8-7.4	1.1

Table 3: Combined analysis of variance for male flowering and yield of maize hybrids under different cropping systems

Traits	MSE	MSG	MSG×E	CV (%)
Male flowering	1593.67*	3.08^{ns}	3.87*	5.75
Grain yield	91.61*	2.82*	3.69*	10.32

*Significant at 0.05 probability level, ns: Non-significant, MSE: Mean square environment, MSG: Mean square genotype, MSG×E: Mean square genotype×environment, CV: Coefficient of variance

Table 4: GGE analysis for male flowering and yield of maize hybrids under different cropping system

		Male flowering			Yield		
Source of variants	df	Mean square	Percentage	Acum (%)	Mean square	Percentage	Acum (%)
PC1	15	3.77*	39.5	39.5	4.23*	46.7	46.7
PC2	13	3.00*	27.2	66.7	2.44*	23.4	70.1
PC3	11	3.23^{ns}	24.8	91.5	2.07^{ns}	16.8	86.9
PC4	9	1.35^{ns}	8.5	100.0	1.96^{ns}	13.1	100.0

*Significant at 0.05 probability level, ns: Non-significant, df: Degree of freedom, Acum: Accumulation, PC1: Principal component 1, PC2: Principal component 2, PC3: Principal component 3, PC4: Principal component 4

Table 5: Summary of selected hybrids based on GGE biplot

		Selected hybrid	
Environment codes	Cropping system	Male flowering	Yield
E1	Maize (2016)	G14, G7, G3	G12, G8
E2	Maize/sweet potato (2016)	G6	G6, G1
E3	Maize (2017)	G14, G7, G3	G9, G10
E4	Maize/sweet potato (2017)	G2, G5, G11	G2, G4, G11

Table 6: Mean of male flowering and grain yield in different cropping system and planting season

	Male flowering (days after planting)				Yield (t ha^{-1})					
	Maize sole cropping		Maize/sweet potato intercropping		Maize sole cropping		Maize/sweet potato intercropping		Sweet potato/maize intercropping	
Codes	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
G1	58.0	43.0	61.0	48.0	7.19	7.09	8.82	6.76	6.93	7.79
G2	55.5	45.0	62.5	50.0	9.83	7.25	6.30	5.99	5.50	7.17
G3	58.0	45.5	62.0	48.0	8.45	5.36	7.56	6.30	8.56	9.91
G4	56.0	45.5	61.0	50.0	9.33	6.62	6.30	6.39	4.64	5.48
G5	57.0	44.5	61.0	50.0	7.25	6.46	10.09	5.20	7.10	6.41
G6	58.5	47.0	62.0	47.5	10.07	6.46	10.09	6.86	9.19	10.88
G7	59.0	44.0	62.0	49.5	7.56	6.11	8.82	7.41	8.14	5.79
G8	55.0	45.0	61.0	50.0	8.82	5.67	7.56	6.02	6.08	3.35
G9	55.5	51.0	61.0	45.0	6.93	6.71	8.82	4.09	8.03	8.74
G10	56.5	46.5	60.0	49.5	8.32	6.68	11.36	3.78	6.24	6.88
G11	55.0	45.5	60.0	50.5	8.95	6.30	8.07	6.76	9.40	5.39
G12	57.5	49.0	60.0	47.5	10.46	6.62	7.56	5.14	9.84	3.70
G13	54.5	49.0	62.5	48.5	7.75	6.93	8.19	6.65	8.23	8.91
G14	57.5	51.5	65.0	48.5	6.43	6.46	8.82	4.28	8.83	6.42

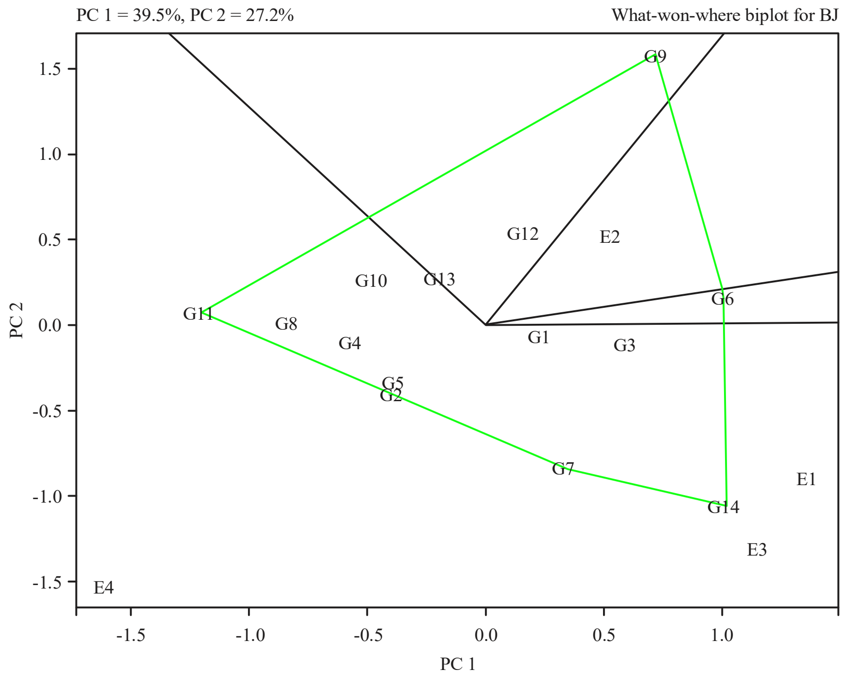

Fig. 1: GGE Biplot for male flowering

E1: Sole cropping rainy season 2017, E2: Maize/sweet potato intercropping rainy season 2017, E3: Sole cropping dry season 2017, E4: Maize/sweet potato intercropping dry season 2017, G1: 1×2, G2: 1×4, G3-1×6, G4: 2×13, G5: 2×15, G6: 3×4, G7: 3×11, G8: 3×13, G9: 6×7, G10: 6×9, G11: 6×11, G12: 6×13, G13: 11×12, G14: PTW2

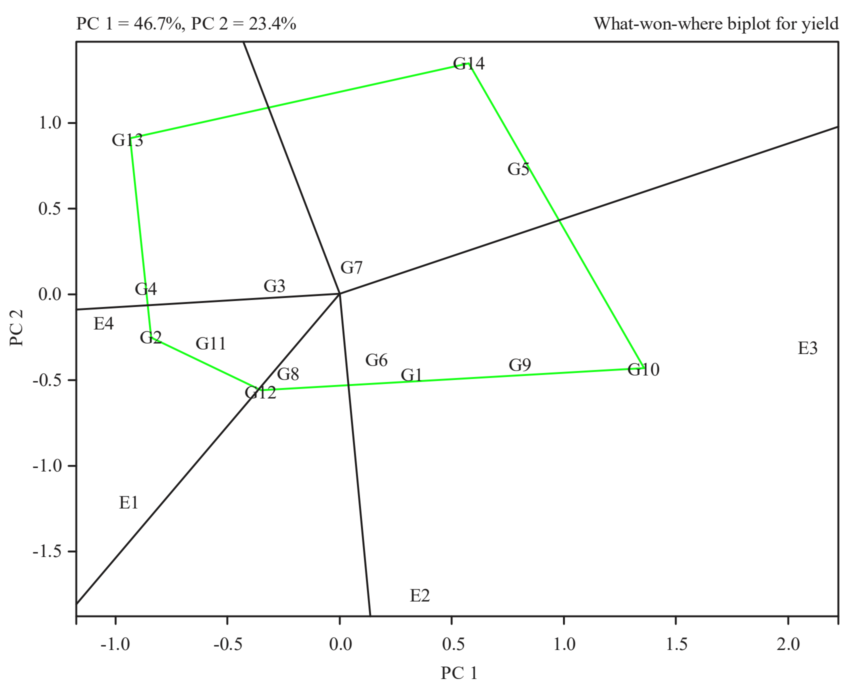

Fig. 2: GGE Biplot for yield

E1: Sole cropping rainy season 2017, E2: Maize/sweet potato intercropping rainy season 2017, E3: Sole cropping dry season 2017, E4: Maize/sweet potato intercropping dry season 2017, G1: 1x2, G2: 1x4, G3-1x6, G4: 2x13, G5: 2x15,G6: 3x4, G7: 3x11, G8: 3x13, G9: 6x7, G10: 6x9, G11: 6x11, G12: 6x13, G13: 11x12, G14: PTW2

Table 7: LER, CRm, CRs in different planting season

	Planting year 2016			Planting year 2017		
Codes	LER	CRm	CRs	LER	CRm	CRs
G1	0.45	2.23	0.45	0.67	1.49	0.67
G2	0.68	1.47	0.68	0.63	1.58	0.63
G3	0.76	1.32	0.76	0.58	1.73	0.58
G4	0.55	1.83	0.55	0.50	2.01	0.50
G5	0.41	2.46	0.41	0.47	2.14	0.47
G6	0.73	1.37	0.73	0.95	1.05	0.95
G7	0.55	1.80	0.55	0.35	2.88	0.35
G8	0.56	1.77	0.56	0.31	3.27	0.31
G9	0.50	1.99	0.50	0.80	1.26	0.80
G10	0.36	2.75	0.36	0.66	1.51	0.66
G11	0.83	1.20	0.83	0.36	2.74	0.36
G12	1.08	0.92	1.08	0.28	3.52	0.28
G13	0.62	1.61	0.62	0.71	1.40	0.71
G14	0.51	1.95	0.51	0.77	1.29	0.77

specific hybrid for this cropping system was G6 (62.0 days after planting = dap, in rainy season 2017), which was the longest male flowering hybrid in this cropping system. Sole maize cropping system-rainy season 2017 (E1) and sole maize cropping system-dry season 2017(E3) were in sector 4 and specific hybrids for the cropping system were G14 (57.5 dap in rainy season 2017 and 51.5 dap in dry season 2017), G7 (59.0 dap in rainy season 2016 and 44.0 dap in dry season 2017) and the earliest flowering hybrid of G2 (55.5 dap in rainy season 2017 and 45.0 dap in dry season 2017). On the other hand, polygon for yield shaped 5 sections of which 2 showed environment appointed to a hybrid at the tip of the polygon. The E2 and E3 were in sector 2, whereas, E1 and E4 were in sector 4. The G9 and G10 were specific hybrids for sole maize cropping system-dry season 2017 (E3), whereas, G6 and G1 were specific hybrids for maize/sweet potato cropping system-rainy season 2017(E2). The G12 and G8 were specific hybrids for sole maize cropping system-rainy season 2017 (E1), whereas, G4, G2 and G11 were specific hybrids for maize/sweet potato cropping system-dry season 2017 (E4).

The yield data of sweet potatoes 7.62$\pm$1.51 and 6.92$\pm$2.10 t ha^{-1} in 2016 and 2017, respectively (Table 6). Contrary to the tuber yield of sweet potato in sole cropping system, the tuber yield of sweet potato in intercropping with maize decreased from 30 and upto 60%. This is an indication of competition among both plants.

The principle of sweet potato planting in intercropping is to minimize the competition that occurs during cultivation. It is necessary to select suitable maize hybrids for intercropping with sweet potato without affecting yield of both sweet potato and maize. The selected maize hybrids suitable for intercropping with sweet potato are presented in Table 7. The ability of sweet potato to compete with maize hybrid is indicated by the high CRs value. The high CRs value was obtained when sweet potato were intercropped with G11 (CRs = 0.83) and G12 (CRs = 1.08) in planting season 2016 and G6 (CRs = 0.8) and G9 (CRs = 0.95) in 2017.

Selection of adaptive maize hybrid under intercropping with sweet potato: Selection of adaptive maize hybrid performance in intercropping with sweet potato based on LER was presented in Table 7. There were six maize hybrids that had LER better than maize hybrid G14 as check hybrid variety, namely: Maize hybrid G3, G6, G11, G12 for planting season 2016 and G6 and G9 for planting season 2017. But only 2 hybrids, G12 and G6 were selected. For G12, it showed LER>1 in intercropping maize-sweet potato intercropping and the G6 had consistent high LER in both planting season 2016 (LER = 0.73) and 2017 (LER = 0.95).

The competition between maize and sweet potato in intercropping is estimated by CR index and is presented in Table 7. The result revealed that CR maize-sweet potato (CRm) was constantly higher than CR sweet potato/maize (CRs) in rainy and dry season 2017. This specified that maize hybrids have better competitiveness than sweet potato since it is stable in intercropping.

DISCUSSION

In this study maize hybrids showed their broad range of variation under different cropping systems and years (Table 2). The variation of male flowering and yield for new Indonesian maize hybrids was due to their broad genetic base, the experimental environments and Genetic$\times$Environment interaction (GEI). Genetic studies on flowering and yield and environment factors affecting their performance had been extensively studied[23]. Many traits of maize are governed by many genes and are inherited by quantitative genetic variations developing from the joined action of multiple genes and environment[23]. Based on this finding, multi-environment evaluation are required to select a stable and an adaptive maize hybrid under intercropping with sweet potato.

This study revealed that GEI acts an important role in the expression of male flowering and yield (Table 3). The GEI had significant role for complex characters[24,25]. As a complex trait, male flowering and yield result from interaction of set combinations of biochemistry reaction from many genes and environment such as soil structure and fertility, rain, temperature of soil and air and their GEI[26]. The GEI is the source of inconsistency for male flowering and yield performance of maize hybrids in various test locations. In specific environments, superior hybrids can reduce the effect of negative factors in that environment but at the same time can increase the effect of positive factors in the environment rising in high yield of hybrid performance. Based on this study, high yield maize hybrids could be developed for intercropping with sweet potato.

Indonesian maize hybrids adapted in different cropping system and planting season as indicated in GGE biplot (Table 4, 5, Fig. 1, 2). In this study, GGE biplot was presented in four sections polygon regions. The number of polygon regions depends on the diverse genetic background of genotypes and distinct environments involved. Some researchers located superior genotypes and environments in at least four regions in which the farthest hybrids were drawn into a polygon of GGE biplot[24,25,27]. They reported various superior genotypes for different environments. If environmental markers were divided into various regions, it shows that distinctive genotypes are superior in different sectors[9]. The environments that are positioned at different sectors show that genotypes in these environments have different yields and ordered as specific genotype. Thus, the environment is able to expose a difference among genotypes.

Sweet potato has two equally important parts, namely shoot and root. The plant stores food reserves at the root, whereas, the shoot section supplies assimilate to be stored at the root to form starch. Although the root part also has the same role in absorbing nutrients and water, when this shoot section is affected by shading it will cause disruption of food supply and indirectly reduce the tuber yield and quality of sweet potato[28] by up to 80%.

In maize+sweet potato intercropping (Table 6), sweet potato experience high stress due to shading, inter specific competition between maize and sweet potato and intra specific competition among sweet potato. Oswald *et al.*[29] explained that broad canopy of maize influence the assimilation process in the shoot section of sweet potato. This stress, together with the occurrence of competition in the roots may also cause disruption in the formation of tuber in sweet potato. This phenomenon can be observed in the present research where tuber yield of sweet potato planted in monocropping for two years was higher than when it was intercropped with maize.

In the recent study, maize hybrid G12 has LER of 1.08 (Table 7). It is justified that the LER value >1 demonstrating the high economic benefit of intercropping[15,30]. This value indicates that intercropping is better than sole cropping in relations of the efficiency of consuming environmental resources for growth or by improved plant density. Early studies[22] described that yield gains in intercropping arises because of divergences in their consumption of resources and their stability better than in sole cropping.

The study showed that CRm was >1.00 but CRs was <1.00 (Table 7). It is suggested that sweet potato are insignificant competitors and it is the appropriate crop in intercropping with maize. There is a positive gain when CR was <1.00 and the crop can be grown in intercropping, but there was negative advantage when >1.00. Some researchers showed that CR index indicate competitive ability of the crops. It is also a valuable index over relative crowding coefficient and aggressivity[11,14,15].

In this study, maize hybrid G3, G6, G11 and G12 were selected in rainy season 2017; whereas hybrid G6, G9 and G13 were selected in dry season 2017. An exception is for G6, the hybrid which exhibited consistent high CRm and CRs value. This result suggested that the hybrid could be advanced as appropriate hybrid in intercropping of maize and sweet potato.

Farmers are interested to cultivate hybrids showing high yield and stable hybrids. In Africa, farmers preferred to select superior maize adapted to specific or broad environment to protect their yield and economic revenue that was influenced by environmental change[24,31]. In the present study, G6 was selected as potential hybrid variety in West Java, Indonesia since it showed high yield and earliness in the 2 distinct cropping systems for 2 different seasons. Also, maize hybrid G6 exhibited consistent high CRm and CRs values, therefore, the hybrid could be developed as suitable hybrid in maize/sweet potato intercropping system.

CONCLUSION

The G×E interaction (GEI) plays an important role for male flowering and yield as well as genotype in this study. The G6 was determined as potential hybrid variety for intercropping with sweet potato since it showed high yield showed consistent high LER and exhibited consistent high CRm and CRs.

Selection of stable and adaptive maize hybrid variety for intercropping with sweet potato requires further multi-environment evaluation in several locations in Indonesia.

SIGNIFICANCE STATEMENT

This study discovers the important role of Genotype×Environment interaction in adaptation of maize in different cropping system and planting seasons. This study will help the researcher to uncover the critical factor of adaptation of new maize hybrids under the abiotic stress. Thus, a new strategy to select new maize hybrid for intercropping with sweet potatoes, may be arrived at.

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