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The Effect of Genotypes and GE Interaction on Starch Content of Cassava

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ABSTRACT

The objective of this study is to explore the effect of genotype and genotype x environment on starch content percentage of 5 cassava genotypes grown under several environments in early and late rainy seasons. The results indicated that there was less seasonal effect on genotypic performance. There was more GE interaction in late rainy season. The sum of squares of GE interaction was partitioned using 3 techniques, viz. linear regression (REG), using Eberhart and Russell (1966) stability, and Additive Main effects and the Multiplicative Interaction (AMMI) model in 2 principal component axes. The AMMI model can explain a large portion of sum of squares, and thus more effective in partitioning the GE interaction SS than the REG technique. Grouping of homogeneous environments using cluster analysis resulted in almost the same genotype ranking in each group. Environmental grouping can then be used to reduce the reversal GE interaction.

Key words : cassava, genotype x environment, regression, AMMI, cluster analysis

INTRODUCTION

A widely used technique for characterizing genotype x environment interactions and to predict varietal response was proposed by Eberhart and Russell (1966). The method requires analysis of stability parameters of crop cultivar performance over a series of experiments. Mean yield of individual genotype is regressed against the environmental index to provide 2 stability parameters. One is a regression coefficient (b_i) for comparing relative response of a particular variety to average of all varieties. Another parameter is the deviation from regression mean square (s_d^2) for measuring how well the predicted response agrees with the observed response. Both parameters defined a desirable variety as one with high mean yield, a regression coefficient equal to 1.0, and the squared deviation from regression as small as possible ($s_d^2 = 0$). The linear regression technique, however, has some deficiencies such as confounding between interaction and main effects, and non-linear response of genotypes to environments (Perkins and Jinks, 1968; Nachit *et al*., 1992). Gauch (1988) proposed the Additive Main effects and the Multiplicative Interaction (AMMI) model for analysing multi-location experiments and compared with analysis of variance, linear regression, and principal component analysis. AMMI can separate main effect of genotype and

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environment, and multiplicative effect of genotype x environment interaction. Using the principal component analysis, the interaction can be devided to principal component axes. He concluded that AMMI model can explain more information when compared with the other methods.

Boonseng *et al.* (1997) reported an AMMI analysis of dry root yield of 5 cassava genotypes grown in early rainy season. SR1 was most stable when compared with the other genotypes but yielded rather low. KU50 was moderately stable and gave high yield in several environments. R60 and R90 performed well in specific environmental condition. Chatwachirawong (1993) studies in sugarcane experiment and indicated that only PCA1 was enough to explain the sum of squares of GE interaction. Results from 3 characters (cane yield, CCS, and sugar yield) showed that the AMMI model can explain more than 90% of the total variation sum of squares. These results were the same as Chatwachirawong and Srinives (1997). This study explored the genotype and genotype x environment effect on the percentage of starch content of 5 cassava genotypes grown under several environments in early and late rainy seasons. The parameters were analyzed using regression (REG) technique and additive main effects and the multiplicative interaction (AMMI) model. Trend line from REG and biplot from AMMI were used to explore desirable genotypes.

MATERIAL AND METHODS

The experiments were conducted in eastern and northeastern of Thailand during early and late rainy seasons of 1992-1993. There were 9 locations in early rainy season, namely, Mukdahan Field Crops Experiment Station (MUK), Maha Sarakham Field Crops Experiment Station (MAH), Rayong Field Crops Research Center (RY), Banmai Samrong Field Crops Experiment Station (BMS), Khon Kaen Crops Research Center (KK), Nonsuwan farmer field in Buri Ram Province (BR), Maung District farmer field (KR), Dankhuntod farmer field, and Seagsang farmer field (SS) in Nakhon Ratchasima Province. There were 2 locations in the late rainy season, namely, Ladbualuang (LAD) and Sikhiu farmer field (SI) in Nakhon Ratchasima Province. Roots were mannally harvested at 12 months and analyzed for starch content by density method (Rieman scale balance).

The REG of Eberhart and Russell (1966) method was used to estimate the stability parameters, viz. regression coefficient (b_i) and deviation from regression (Dev. MS). These parameters are defined with the following model:

$$Y_{ij} = \mu + \alpha_i + \beta_j I_j + \delta_{ij}$$

In the AMMI analysis the model is

$$Y_{ij} = \mu + \alpha_i + \beta_j + \sum_{n=1}^{N} \lambda_n \xi_{in} \eta_{jn} + \delta_{ij}$$

where Y_{ij} is the starch content of the i^{th} genotype at j^{th} environment, μ is the grand mean, α_i is the mean of the i^{th} genotype over all environments, β_j is the regression coefficient that measures the response of the i^{th} genotype to varying environments, I_j is the environmental index, ε_{ijk} is the unexplained deviation of i^{th} genotype at the j^{th} environment, λ_n is the square root of the eigenvalue of the PCA axis n, ξ_{in} and η_{jn} are the genotype and environment PCA score for the PCA axis n, *N* is the number of PCA axes retained in the model, and δ_{ij} is the residual term.

In REG model, a desirable genotype should have high starch content, a regression coefficient equal to 1.0, and the squared deviation from regression approximate to 0.0. While in AMMI model, PCA1 axis of 0.0 measures a stable genotype. The remaining PCA axes from AMMI model can be used to accurately estimate starch content percentage. High starch content and the near zero

PCA1 together identify a desirable genotype. Finally, cluster analysis was used to separate the environments into homogeneous groups. Thus distance between the environment and its group can be measured from standardized squares euclidean distance. The varieties were grouped using incremental sum of squares method. Only data from the percentage of starch content of 5 cassava genotypes, namely Kasetsart 50 (KU50), Rayong 1 (R1), Rayong 60 (R60), Rayong 90 (R90) and Sriracha 1 (SR1), were analysed in this experiment.

RESULTS AND DISCUSSION

Analysis of variance of starch content percentage was given in Table 1. The sum of squares of environments, genotypes, and genotype x environment (GE) interaction were 50.21%, 41.77% and 8.02% for early rainy season, and 45.46%, 39.89% and 14.65% for late rainy season, respectively. As the genotype SS expressed difference in both seasons, the cassava breeder should emphasize on selecting not only dry root yield but also the percentage of starch content during screening a large number of genotypes in a breeding program. In late rainy season, GE interaction effect increased while environmental effect decreased. The REG technique showed that Gen. x Env. (linear) SS as seperated from Env. SS + (Gen. x Env.) SS and accounted for 0.56% and 6.51% in early and late rainy seasons. These indicated that there were no differences among genotypes in their response to the environmental indices.

In Table 1, the Gen. x Env. (linear) SS was not a large proportion of the GE interaction when compared with the Env. (linear) SS and Residual

Table 1 The REG and AMMI variance components of starch content percentage of 5 cassava genotypes grown in early and late rainy seasons.

Sources of Variation	Early Rainy Season			Late Rainy Season		
	df	SS	%SS	df	SS	%SS
ANOVA						
Environments (Env.)	8	499.66	50.21	10	1384.20	45.46
Genotype (Gen.)	4	415.61	41.77	4	1214.92	39.89
Gen. x Env.	32	79.81	8.02	40	446.32	14.65
REG Model						
Env. + (Gen. x Env. Int.)	40	579.46		50	610.20	
Env. (linear)	1	499.66	86.23	1	461.42	75.61
Gen. x Env. (linear)	4	3.23	0.56	4	39.71	6.51
Residual	35	76.57	13.21	45	109.07	17.88
AMMI Model						
Gen. x Env. Int.	32	79.81		40	446.32	
PCA1	11	38.79	48.61	13	272.12	60.97
PCA2	9	22.33	27.98	11	104.57	23.43
Residual	12	18.68	23.41	16	69.63	15.60

SS. Hence, only the Dev. MS was considered important. Dev. MS, however, might be a biased estimator when it was analysed based on a few environments (Eberhart and Russell, 1966). For AMMI model, partitioning GE interaction to PCA1 and PCA2 had the combined percentage of 76.59 and 84.40 %, respectively. These results showed less effect of GE when compared with genotype and environment effects. So, the AMMI model was used to estimate the percentage of starch content.

In both seasons, all cassava genotypes showed the same performance to different environments in which b_i and Dev. MS were not significantly different from 1.0 and 0.0 (Table 2). Thus REG technique was not appropiate for these data sets. Figure 1 showed the regression lines that

Table 2 Parameters analysed from regression technique of 5 cassava genotypes grown in early and late rainy seasons.

Genotype	Early Rainy Season			Late Rainy Season		
	b_i	Dev. MS	Mean 1/	b_i	Dev. MS	Mean 1/
KU50	0.84	2.67	21.36 a	0.64	0.74	26.06 a
R1	1.03	0.90	15.33 b	1.43	3.50	19.42 d
R60	1.07	1.46	15.35 b	0.96	2.69	21.21 c
R90	1.04	2.09	21.79 a	0.75	2.43	26.32 a
SR1	1.01	3.80	21.46 a	1.22	2.75	24.16 b

1/ In a column, means followed by a common letter are not significantly different at $P \leq 0.05$ by LSD

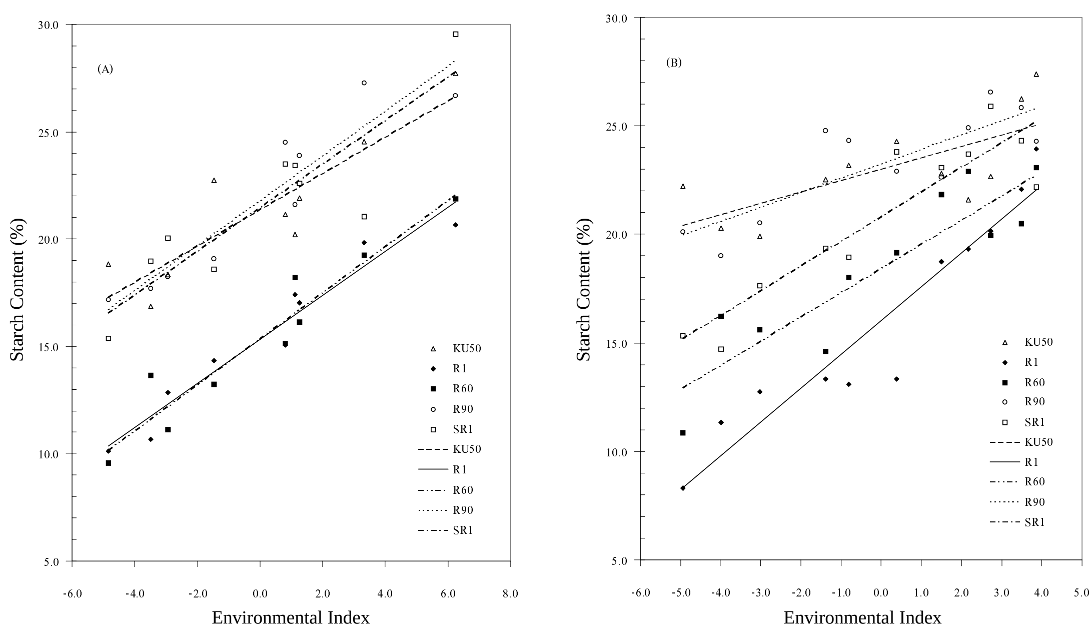

Figure 1 Linear regression lines of 5 cassava genotypes grown under 9 and 11 environments in early (A) and late (B) rainy seasons, respectively.

cassava genotypes can be seperated into 2 groups in early rainy season. The first group comprised 3 genotypes (R90, SR1 and KU50), while the second group had 2 genotypes (R1 and R60). In late rainy season, genotype R1 had larger Dev. MS which affected sensitivity of the significance of the regression coefficient (b_i = 1.43), resulted in no different from 1.0. This data set should be modified either grouping homogeneous environments before REG analysis or using other analytical models.

Results form the AMMI model are given in Table 3. The average percentage of starch content had large effect on several environments. The average starch content at BMS, a good environment, was 25.30%. DAN had average starch content only 14.21% which was considered a poor environment. PCA1 and PCA2 on AMMI model, seperated from the GE interaction, showed statistical singnificance. Hence, the percentages of starch content were estimated from the main effect (genotype and environment) with 2 retained principal component axes. The estimated starch content are shown in Table 3 and 4 for early and late rainy seasons. Using cluster analysis to group the homogeneous environments in both seasons resulted in three groups. The arrangement of genotypes ranking were the same in each environment. Therefore, cluster analysis technique can reduce the reversal GE interaction effect. Only three genotypes (KU50, R90 and SR1) were top ranking in some environments.

Table 4 and Figure 3 explored the results of AMMI model in late rainy season. The percentage of starch content under 11 environments had a range from 26.52 to 19.02 %. The top genotype ranking was R90 for 8 environments, and SR1 for 3 environments, but KU50, R1 and R60 were not found in the top ranking. Genotype PCA1 of 5 cassavas, namely KU50, R1, R60, R90, and SR1, were -1.61, 2.79, 1.45, -1.84 and -0.79, respectively. Cluster analysis can separate the environments into 3 groups. Group I consisted of 4 environments

Table 3 Estimated percentage of starch content, PCA scores, and genotypic ranking in each environment (in parenthesis), and environmental groups of 5 cassava genotypes grown in early rainy sonson.

Env. Group	Env.	Genotypes					
		KU50	R1	R60	R90	SR1	Mean[1/]
I	BMS	27.62 (2)	20.97 (5)	21.50 (4)	26.74 (3)	29.69 (1)	25.30 a
	BR	21.18 (3)	16.11 (5)	16.60 (4)	22.71 (2)	22.73 (1)	19.87 c
	SS	20.27 (3)	16.28 (5)	17.42 (4)	22.94 (2)	23.92 (1)	20.17 c
	KK	18.65 (2)	12.00 (5)	12.24 (4)	17.99 (3)	19.67 (1)	16.11 e
	KR	22.07 (3)	16.76 (5)	16.87 (4)	23.52 (1)	22.32 (2)	20.31 c
	MAH	16.52 (3)	11.57 (5)	12.43 (4)	17.96 (2)	19.36 (1)	15.57 ef
II	DAN	18.74 (1)	10.63 (4)	9.53 (5)	16.86 (2)	15.32 (3)	14.21 f
	MUK	22.71 (1)	13.87 (4)	12.62 (5)	19.83 (2)	18.93 (3)	17.59 d
III	RY	24.49 (2)	19.77 (4)	18.93 (5)	27.53 (1)	21.17 (3)	22.38 b
Genotype	PCA1	1.25	0.44	-0.50	0.72	-1.92	
PCA score	PCA2	-1.53	0.39	0.75	1.09	-0.69	

1/ In a column, means followed by a common letter are not significantly different at P ≤ 0.05 by LSD

Table 4 Estimated percent of starch content, PCA scores, and genotypic ranking in each environment (in parenthesis), and environmental groups of 5 cassava genotypes grown in late rainy season.

Env. Group	Env.	Genotypes					
		KU50	R1	R60	R90	SR1	Mean1/
I	BMS	26.87 (2)	23.58 (5)	23.98 (4)	26.72 (3)	27.68 (1)	25.77 a
	DAN	27.06 (2)	22.20 (5)	23.14 (4)	27.03 (3)	27.23 (1)	25.33 ab
	KR	28.22 (2)	19.14 (5)	21.42 (4)	28.44 (1)	27.28 (3)	24.90 ab
	MAH	28.37 (2)	22.02 (5)	23.19 (4)	28.26 (3)	29.51 (1)	26.27 a
II	BR	21.55 (2)	15.41 (5)	17.16 (4)	21.86 (1)	19.13 (3)	19.02 d
	LAD	25.32 (2)	16.07 (5)	19.07 (4)	25.99 (1)	20.61 (3)	21.41 c
	RY	26.36 (2)	19.26 (5)	21.20 (4)	26.66 (1)	24.29 (3)	23.55 b
	SI	24.37 (2)	10.63 (5)	14.63 (4)	25.02 (1)	20.94 (3)	19.12 d
	SS	28.93 (2)	23.09 (5)	24.74 (4)	29.22 (1)	26.62 (3)	26.52 a
III	KK	22.68 (2)	16.50 (5)	18.81 (3)	23.36 (1)	17.18 (4)	19.71 cd
	MUK	26.90 (2)	25.70 (4)	25.96 (3)	26.97 (1)	25.28 (5)	26.16 a
Genotype	PCA1	-1.61	2.79	1.45	-1.84	-0.79	
PCA score	PCA2	0.74	0.00	0.83	1.18	-2.75	

1/ In a column, means followed by a common letter are not significantly different at P ≤ 0.05 by LSD

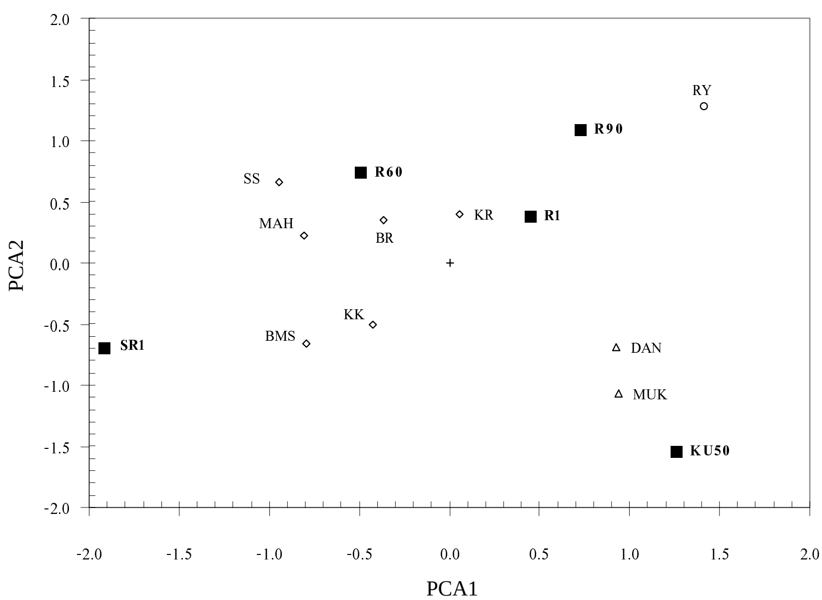

Figure 2 Biplot showing two dimensions of PCA1 and PCA2 axes on the percentage of starch content in roots of 5 cassava genotypes grown in 9 environments in early rainy season.

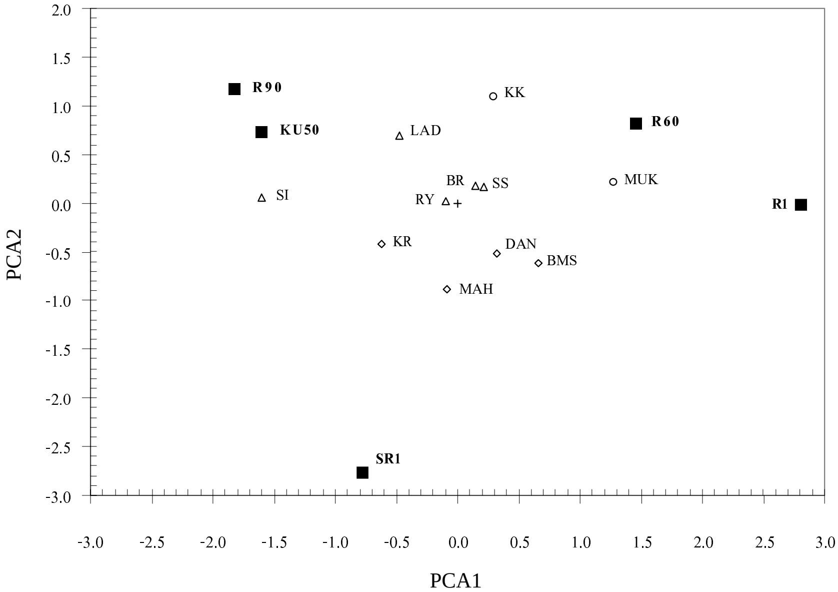

Figure 3 Biplot showing two dimensions of PCA1 and PCA2 axes on the percent of starch content of 5 cassava genotypes grown in 11 environments in late rainy season.

(BMS, DAN, KR and MAH) which SR1, KU50, R90, R60 and R1 ranking form high to low percentage of starch content. Group II consisted of 5 environments that gave the same genotype ranking as R90, KU50, SR1, R60 and R1. Group III had KK and MUK environments. As a result of grouping environment, each group showed the same genotype ranking. For this reason, reseacher can use cluster analysis technique to reduce the effect of GE interaction.

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