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Stability Analysis of Six Super Sweet Corn Cultivars under Chemical and Organic Fertilizer Growing Systems

Pramote Pornsuriya[1*] and Pornthip Pornsuriya[1]

Abstract

The research aimed to evaluate the stability of six super sweet corn cultivars viz. Hibrix#3, Topsweet#801, Sugar#75, Sugarstar, Aurora, and Insee#2. They were planted at Faculty of Agriculture and Natural Resources, Rajamangala University of Technology Tawan- ok, Chonburi province in 5 environments: organic, chemical, chemical + organic fertilizer grown in the first season (December 2010 – March 2011), and organic and chemical fertilizer grown in the second season (April – June 2011). In each environment, randomized complete block design (RCBD) with 4 replications was used. After having homogeneity test for error variances, combined analysis of variance was performed and showed that the two important characters (ear length and kernel sweetness) were significant ($P < 0.01$) for the effect of genotype x environment interaction. Stability parameters were analyzed for these characters using Eberhart and Russell model, which defined cultivars with positive phenotypic index ($P_i > 0$), regression coefficient around unity ($b_i = 1$), and deviation from regression value around zero ($S^2_{di} = 0$) were considered highly stable. The results revealed that Topsweet#801 showed high stability in ear length. For kernel sweetness, Sugarstar possessed high stability, whereas Topsweet#801 had positive phenotypic index ($P_i > 0$) but its regression coefficient was more than 1 ($b_i > 1$), thus it would be classified as suitable for rich environments.

Keywords: *Zea mays saccharata*, stability, genotype-environment interaction

Introduction

Super sweet corn (*Zea mays* L. *saccharata* (Sturtev.) L.H. Bailey) (Porcher, 2005) is one of the most important vegetable grown in Thailand. Planting areas of super sweet corn in Thailand in 2013 are approximately 33,218 ha (Department of Agricultural Extension, 2014). Super sweet corn is generally named for shrunken-2 types that have more sugar content than sugary types, which are commonly called as normal sweet corn or sweet corn (Lerner and Dana, 2001). Yellow variety super sweet corn has significant levels of phenolic flavonoid pigment antioxidants such as β-carotenes, lutein, xanthins and cryptoxanthin pigments along with vitamin A. 100 g fresh kernels provide 208 IU of vitamin A, 0.20 mg Thiamine, 0.06 mg Riboflavin, 1.70 mg Niacin,6.8 mg Ascorbic Acid and 0.06 mg Vitamin B_6 (Maynard and Hochmuth, 2007).

Crop cultivars with different genotypes generally have high yield performance or other characters if they were planted in suitable or rich environments, but they may give high or low yield in

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diverse environments since each cultivar may have different response to each environment. Genotype-environment interaction is definitely significant in the development and evaluation of plant cultivars, because it affects yield performance of plant cultivars grown under various environments (Hebert *et al.*, 1995; Detios *et al.*, 2006). It also provides information about the effects of different environments on cultivar performance and plays a key role for assessment of performance stability of the breeding materials (Moldovan *et al.*, 2000). The concept of stability has been evaluated in several aspects and through several biometrical methods (Lin *et al.*, 1986; Crossa, 1990). Eberhart and Russell (1966) proposed the model that has been widely used to study stability parameters. They defined a stable cultivar as having unit regression over the environments and minimum deviation from regression. Therefore, a cultivar with high mean yield over the environments, unit regression coefficient (b=1) and deviation from regression as small as possible ($S^2_{di} = 0$), will be considered as a stable cultivar. To study stability of genotypes the multilocational trials over a number of years are conducted. Sometimes the unilocational trials can also serve the purpose provided different environments are created by planting experimental material at different dates of sowing, using various spacings and doses of fertilizers and irrigation levels etc. (Tehlan, 1973; Luthra *et al.*, 1974; Ottai *et al.*, 2006). Because of the important roles of genotype-environment interaction on crop production and plant breeding program, thus stability parameters have been widely studied in various crops (Babic *et al.*, 2006; Karadavut *et al.*, 2010; Biswas *et al.*, 2012) including super sweet corn (Cordea *et al.*, 2011; Ardelean *et al.*, 2012).

Since the trend of organic and low input farms in growing plants has widely interested recently. Thus, apart from the natural environmental variables (seasons and places), this study purposes to determine stability of six super sweet corn hybrid cultivars under chemical and organic fertilizer growing systems.

Materials and Methods

Materials: Six super sweet corn hybrid cultivars namely Hibrix#3, Topsweet#801, Sugar#75, Sugarstar and Aurora were obtained from seed companies (markets), and Insee#2 from National Corn and Sorghum Research Center.

Experimental application: The seeds of six sweet corn cultivars were sown at the experimental field of Department of Plant Production Technology, Faculty of Agriculture and Natural Resources, Rajamangala University of Technology Tawan- ok, Chonburi province during December 2010 – March 2011 and April – June 2011 in the first and the second season, respectively. They were conducted in randomized complete block design (RCBD) with 4 replications. Each experimental unit (plot size) was 1 $\times$ 3 m^2, 2 rows per plot, with 25 $\times$ 75-cm spacing (plant $\times$ row), 24 plants per plot (1 plant/hill). The experiment was repeated for five modified environments divided into two successive seasons as the following.

Environment 1: organic fertilizer (cow dung 43.75 ton/ha) in the first season.

Environment 2: chemical fertilizer (500 kg/ha of 15N-15P-15K and 187.5 kg/ha of 46N-0P-0K) in the first season.

Environment 3: organic fertilizer (cow dung 21.87 ton/ha) + chemical fertilizer (500 kg/ha of 15N-15P-15K and 187.5 kg/ha of 46N-0P-0K) in the first season.

Environment 4: organic fertilizer (cow dung 43.75 ton/ha) in the second season.

Environment 5: chemical fertilizer (500 kg/ha of 15N-15P-15K and 187.5 kg/ha of 46N-0P-0K) in the second season.

Data were recorded for plant and ear characters (averaged from10 plants and 10 ears per plot, respectively), un-husked and husked ear yield/hectare (calculated from un-husked and husked ear weight per plot, respectively). Homogeneity tests of error variance of all environments were determined using Bartlett' test (Little and Hills, 1978). Combined analyses were performed only for characters with having homogeneity of error variance (stem diameter, un-husked and husked ear weight, ear length (husked), un-husked and husked ear yield/hectare and kernel sweetness) to investigate genotype-environment interactions (McIntosh, 1983). Stability parameters were calculated for characters possessing significance of genotype-environment interaction according to the model of Eberhart and Russell (1966) as illustrated by Sharma (2008) and Singh and Chaudhary (2012).

Note: The present study was intended to determine the stability of each super sweet corn cultivar only. The study on cultivars and environments comparisons was separated to another report.

Results and discussion

Combined analysis of variance:

Homogeneity of variance for all five environments was detected in un-husked ear weight, husked ear weight, ear length and stem diameter, whereas un-husked and husked ear yield per ha and kernel sweetness were discovered the homogeneity of variance under four environments. Thus, combine analyses were performed according to these characters under five and four environments, respectively. Cultivar-environment interactions were significant for ear length ($P < 0.05$) and kernel sweetness ($P < 0.01$). The combined analyses of variance for these characters were shown in Table 1 and 2.

Table 1: Analysis of variance for six super sweet corn hybrid cultivars under five environments having homogeneity of variance.

Source of variance	df	Mean Square			
		Un-husked ear weight (g)	Husked ear weight (g)	Ear length (cm)	Stem diameter (cm)

Cultivars (C)	5	47,491.98**	26,008.92**	17.49**	0.14*
Environments (E)	4	46,758.11**	20,696.75**	2.36	7.13**
Rep. in Environments	15	1,903.72	1,044.71	0.55	0.02
C x E	20	1,375.10	732.70	1.04*	0.07
Error	75	1,207.66	679.88	0.52	0.04

*Significant at $P < 0.05$, **significant at $P < 0.01$.

Table 2: Analysis of variance for six super sweet corn hybrid cultivars under four environments having homogeneity of variance.

Source of variance	df	Mean Square		
		Un-husked ear yield (kg/ha)	Husked ear yield (kg/ha)	Kernel sweetness (°Brix)
Cultivars (C)	5	52,592.28**	27,978.40**	1.22
Environments (E)	3	130,358.72**	62,377.76**	59.71**
Rep. in Environments	12	3,060.11	1,237.85	0.19
C x E	15	3,024.90	2,374.39	0.66**
Error	60	3,353.86	2,352.39	0.16

**Significant at $P < 0.01$.

Stability analysis:

The pooled analysis of variance elucidated by Eberhart and Russell (1966) was conducted for ear length and kernel sweetness as shown in Table 3. The results indicated that cultivars x environments were significantly different ($P < 0.05$) for both characters, implied that these cultivars had different genetic background and environments used (organic and chemical fertilizers) had different effects on plant cultivars, which resulted the expression of the characters. The significance of e (linear) for both characters indicated that variation among environments was linear. A linear environmental variance would signify unit changes in environmental index for each unit change in the environmental conditions (Sharma, 2008). Cultivar-environment (linear) interaction was significant ($P < 0.01$) for kernel sweetness, which revealed that there were genetic differences among genotypes for their regression on the environmental index. Pooled deviation from regression was detected for ear length ($P < 0.05$), suggested that performance of different cultivars fluctuated significantly from their respective linear path of response to environments. However, on the analyzing of the individual cultivar fluctuation from linearity, only the two cultivars Sugar#75 and Sugarstar fluctuated significantly ($P < 0.05$). Insignificant pooled deviation for kernel sweetness signified that all cultivars were close to linear response (Table 3).

Table 3: Pooled analysis of variance for six super sweet corn hybrid cultivars under five and four environments, according Eberhart and Russell's model.

Ear length (5 environments)			Kernel sweetness (4 environments)		
Source of variance	df	MS	Source of variance	df	MS
Cultivars (C)	5	4.372**	Cultivars (C)	5	0.304**
Environments (E)	4	0.589	Environments (E)	3	14.927**
C x E	20	0.261*	C x E	15	0.165*
E + (V x E)	24	0.316	E + (V x E)	18	2.626**
E (linear)	1	2.356**	E (linear)	1	44.782**
C x E (linear)	5	0.219	C x E (linear)	5	0.366**
Pooled deviation	18	0.231*	Pooled deviation	12	0.054
Hibrix#3	3	0.121	Hibrix#3	2	0.111
Topsweet#801	3	0.328	Topsweet#801	2	0.001
Sugar#75	3	0.399*	Sugar#75	2	0.050
Sugarstar	3	0.457*	Sugarstar	2	0.041
Aurora	3	0.037	Aurora	2	0.002
Insee#2	3	0.043	Insee#2	2	0.115
Pooled error	90	0.131	Pooled error	72	0.041

*Significant at $P < 0.05$, **significant at $P < 0.01$.

Stability parameters:

Ear length: Topsweet#801 had the highest positive phenotypic index (P_i) for ear length, regression coefficient around 1.0 ($b_i = 0.81$), and small deviation from regression (not different from zero), thus it was consider as a stable cultivar (Table 4). Phenotypic index is greatly useful to facilitate identification of poor (negative P_i) and highly potential (positive P_i) genotypes without referring every time to genotypic mean (Sharma, 2008). Regression coefficient for ear length (b_i), which was the linear regression of the performance of each cultivar under different environments on the environmental means over all the genotypes (Singh and Chaudhary, 2012), ranged from 0.04 to 1.95. The great variation in regression coefficient indicates the different responses of cultivars to environmental changes (Akcura *et al.*, 2005). Sugarstar also had highly positive phenotypic index and regression coefficient around 1 ($b_i = 0.72$), but its deviation from regression was significantly different from zero (S^2_{di} = 0.457). The higher value of S^2_{di} signified that there was high sensitivity to environmental changes, thus this cultivar quite gave high performance when environmental conditions were conductive (Arshad *et al.*, 2003). Zubair et al. (2002) also suggested that if regression coefficients of the genotypes are not significantly different from 1, the stability of these genotypes should be judged upon other two parameters i.e. genotypic mean (as used by phenotypic index; P_i in this study) and the value of deviation from regression (S^2_{di}).

Kernel sweetness: Sugarstar was considered as a high stable cultivar for kernel sweetness because it had high phenotypic index (P_i = 0.46), regression coefficient equal to the unity (b_i = 1.18) and small deviation from regression (S^2_{di} = 0.041) (Table 5). Topsweet#801 also had positive phenotypic index for kernel sweetness but its regression coefficient was significantly more than 1.0, thus it would be classified suitable for rich environments. Whereas Aurora was considered suitable for poor environments since its regression coefficient was significantly less than 1.0.

Table 4: Stability parameters estimated for ear length of six super sweet corn hybrid cultivars under five environments.

Cultivars	Mean ear length (cm)	Phenotypic index (P_i)	Regression coefficient (b_i)	Deviation from regression (S^2_{di})
Hibrix#3	20.53	0.46	0.04	0.121
Topsweet#801	21.03	0.97	0.81	0.328
Sugar#75	19.71	-0.35	0.79	0.399*
Sugarstar	20.69	0.63	0.72	0.457*
Aurora	20.00	-0.07	1.78	0.037
Insee#2	18.42	-1.64	1.95	0.043
Mean	20.06			

*Significantly different from 0 at $P < 0.05$.

Table 5: Stability parameters estimated for kernel sweetness of six super sweet corn hybrid cultivars under four environments.

Cultivars	Mean kernel sweetness (°Brix)	Phenotypic index (P_i)	Regression coefficient (b_i)	Deviation from regression (S^2_{di})
Hibrix#3	13.08	-0.22	0.92	0.111
Topsweet#801	13.52	0.22	1.14**	0.001
Sugar#75	13.11	-0.20	0.75	0.050

Sugarstar	13.76	0.46	1.18	0.041
Aurora	13.13	-0.17	0.76**	0.002
Insee#2	13.22	-0.09	1.25	0.115
Mean	13.30			

**Significantly different from 1.0 at *P < 0.01*.

Eberhart and Russell (1966) emphasized that both linear (b_i) and non-linear (S^2_{di}) components of genotype-environment interaction are necessary for judging the stability of a genotype. A regression coefficient approximately 1.0, along with deviation from regression equal to zero and positive phenotypic index, indicated average stability (Sharma, 2008). Genotypes with regression values above 1.0 were classified as high sensitivity to environment change (below average stability) and great specificity of adaptability to rich environments. A regression coefficient below 1.0 provides a measurement of greater resistance to environmental change (above average stability). Cultivars with this value were considered having high adaptability to poor environments (Wachira *et al.*, 2002).

Environmental index (I_j):

Environmental index directly reflects the poor or rich environment in terms of negative and positive I_j, respectively. For ear length, environment 3 (organic + chemical fertilizer, 1st season) had the highest and positive environmental index of 0.33 (Table 6), thus it was the favorable environment. Whereas, environment 4 (organic fertilizer, 2nd season) was the most favorable for kernel sweetness (Table 7).

Table 6: Environmental mean ($\bar{e}$) and Environmental index (I_j) for ear length of six super sweet corn cultivars.

	Ear length (cm)					Mean
	Env.1	Env.2	Env.3	Env.4	Env.5	
Environmental mean ($\bar{e}$)	19.99	20.23	20.39	19.56	20.14	20.06
Environmental index (I_j)	-0.07	0.17	0.33	-0.50	0.08	0.00

Table 7: Environmental mean ($\bar{e}$) and Environmental index (I_j) for kernel sweetness of six super sweet corn cultivars.

	Kernel sweetness (°Brix)				Mean
	Env.1	Env.2	Env.4	Env.5	
Environmental mean ($\bar{e}$)	12.87	11.40	14.53	14.49	13.32

Environmental index (I_j)	-0.45	-1.93	1.21	1.17	0.00

Conclusions:

Among the studied characters of the six cultivars grown in five environments under chemical and organic fertilizer growing systems, only ear length and kernel sweetness were found significance of cultivar-environment interaction. The results from stability parameters for ear length revealed that Topsweet#801 was the most stable cultivar, and Sugarstar was considered as a sensitive cultivar suitable for favorable environmental conditions. For kernel sweetness, Sugarstar was a stable cultivar recommended for a wide range of environments, whereas Topsweet#801 was classified suitable for rich environments.

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