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ROLES OF CALCIUM AND MAGNESIUM AS SELECTION FACTORS IN SWEET CORN QUALITY IMPROVEMENT ON ACIDIC RED-YELLOW PODSOLIC SOIL

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ABSTRACT

The cultivation of sweet corn (*Zea mays* L. spp*. saccharata* {Sturt.} Bailey) on acidic red-yellow podsolic (RYP) soil in Lampung, Indonesia was hampered by the low fertility and pH of the soil. Soil amendment with Ca and Mg would improve growth and development of the sweet corn cultivars, as well as differentiating environments in selecting for adaptive cultivars. Aglime, dolomite, Portland cement, and a mixture of 3 aglime: 2 dolomite (w/w) were applied on LASS Yellow-Round (Y-R), LASS Yellow-wrinkle (Y-w), Bicolor and LAS Yellow-wrinkle (Y-w). The results indicated that the kinds of Ca and the doses apllication were capable to differentiate the sweet corn cultivars. Aglime 400 kg ha^{-1} was the best treatment to modify plant environment as selection factor followed by cement 400, dolomite 200 and aglime-dolomite mixture 400 kg ha^{-1}. They improved the growth of the cultivars as well. The characters of interest of the cultivar had complied with those of commercial standard, except for plant height, ear diameter, and kernel-rows ear^{-1}. However, since the genetic variation and broad-sense heritability values for those characters were essentially zero, the subsequent improvement would require genes from the outside populations.

Keywords: calcium; magnesium; sweet corn; *Zea mays* spp*. saccharata*

INTRODUCTION

The cultivation of sweet corn (*Zea mays* L. spp. *saccharata* {Sturt.} Bailey) in the Province of Lampung, Indonesia was hampered by the fact that the soil was dominated by RYP low in fertility and pH, also the limited cultivars offer in the market (Prihastuti and Sudaryono, 2013). Since the sweet-corn cultivars were mainly imported, they face problem with adaptability exposed. Hikam *et al*. (2008) has developed sweet corn cultivars: LASS (Lampung Super Sweet), LAS (Lampung Sugary), and LAGB (Lampung Golden Bantam) using shrunken (shsh), sugary (susu), and sugary-enhancer (sese) genes, respectively. The cultivars were crossed to Srikandi cultivar to increase their vegetative vigor and resistance to insects and diseases, LASS was crossed to LAW (Lampung White) cultivar to develop bicolor cultivar (Hikam, 2003). Since Srikandi and LAW were non-sweet, round kernel genotypes, hybrid progenies so the result were all of yellow-round kernels. The hybrid progenies were selfed to develop segregating-type sweet corn cultivars with yellow-round, yellow-wrinkle, white-round, white-wrinkle, and bicolor with all possible combination. Both the round and wrinkle kernel progenies were used to develop segregating and true type sweet corn cultivars, respectively.

The progenies were tested on a RYP Lampung soil characterized as low in fertility and pH. Agricultural lime (aglime) was the cheapest material to help increasing the pH. However, a dose of 5–10 t aglime ha^{-1} was prohibited for aglime to increase the pH at a 0.2–0.4 scales (UKAG, 2015). Calcium was absorbed by plants in form of Ca^{2+}; 71.5 % of aglime. Corn plants required 15 ppm of Ca in the soil solution, but in general the Ca concentration 100–400 ppm was required since the absorption of Ca was limited to the non-suberized area at the tips of root hairs. Dayod *et al*. (2010) indicated that the high concentration of Ca in the rhizosphere was not correlated to the concentration of Ca in plant tissues since the absorption of Ca was controlled genetically. Since the diameter of Ca^{2+} was greater than that of K^{+}, Ca would be outcompeted with the smaller K in the system of ion transport. The Ca/K competition became important in the application and absorption of K since the deficiency of K resulted by

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leaching and movement of soil water could be substituted by the immobile Ca.

The Ca deficiency in plant tissues was rarely recognized, but Ca in excess hampered growth. The Ca deficiency induced the diseases of fruit cracking on tomatoes, black fruit-pit on apple and empty beans on peanuts. The symptoms were easily found in a RYP soils characterized by having low pH and base saturation, and accumulation of Al and Fe to a deleterious level.

Previous study by Vanneste and Friml (2013) showed that Ca was important to enhance the gravitropism of roots. Calcium released by endoplasmic reticulum would activate calmodulin (DeFalco *et a*l., 2010) which in turn would push Ca and auxin to root caps. Accumulation of Ca in the root caps caused asymmetry in the auxin accumulation to cause the root to bend on the side of the accumulation (Muday and Rahman, 2008). Hence, the positive gravitropism occurred. Calcium accumulation in cytosols induced the elongation of root cells (Demidchick and Maathuis, 2007), thus induced the elongation of root hairs (Grierson *et al*., 2014). Calcium was also important in maintaining the structure of cell walls and membranes, as counter-cation regulating K^+/Na^+ ratio in cytosols and vacuoles. In cytosols, Ca performed as intracellular messenger (Kumar *et al*., 2015).

Magnesium was mainly applied in form of dolomite (16.4% Ca + 9.99% Mg) and a concentration of 24 ppm in soil solution was considered adequate for many plants (UKAG, 2015). Plant biomasses comprised of around 0.2% Mg^{2+}. The Mg deficiency was indicated by chlorosis on the veins and midribs of older leaves starting from the tips (die-back). In several cases, the deficiency of Mg was indicated by a brighter color due to the reduction of chlorophyll synthesis. Magnesium was the cation important in the chlorophyll synthesis as the central ion bound the four pyrrole rings. Magnesium was also important as coenzyme in glycolysis reactions and biochemistry reactions required ATP such as hexokinase: glucose (glu) + ATP → glu-6P +ADP; and Glu-6 phosphatase: glu-6P + ADP →glu + ATP (Nelson and Cox, 2008). Magnesium was essential in the synthesis of amino acids, fatty acids and oil, sucrose and carbohydrates, and hence in seed growth.

This research intended to study the adaptation of sweet corn cultivars developed and selected on the RYP Lampung soils. Aglime and dolomite were applied at fertilizer rate 200–400 kg ha^{-1} to supply for Ca and Mg as well as to improve pH in the rhizosphere. Besides performing to improve the growth and development of the sweet corn cultivars, calcium and magnesium would perform as differentiating media in selecting adaptable cultivar. Therefore, genetic variance ($\sigma^2 g$), broad-sense heritability (h^2_{BS}), and genetic coefficient of variation (CVg) for characters of interest were predicted by means of expected mean-squares calculated in the analyses of variances.

MATERIALS AND METHODS

The research was accomplished in Rajabasa Village, South Lampung, Indonesia dominated by Lampung red-yellow podsolic soil in March–June 2012. The land was a dry land without irrigation at 80 m above sea level. The soil fertility level was low with a pH ≤ 5.8.

The research tested four parental populations of true-type (wrinkle kernel) sweet corn: LASS Yellow-Round (LASS Y-R); LASS Yellow-wrinkle (LASS Y-w), Bicolor, and LAS Yellow-wrinkle (LAS Y-w). The parental populations were developed by Hikam (2003) as followed:

(1) LASS Y-R super sweet was a progeny having yellow-round kernels derived from the cross of ♀Srikandi X ♂ULSS3 which then was selfed and selected for yellow-round kernels (a mixture of genotypes CCShSh and CCShsh);

(2) LASS Y-w super sweet was a progeny with yellow-wrinkle kernels derived from the cross of ♀Srikandi X ♂ULSS3 which then was selfed and selected for yellow-wrinkle kernels (genotype CCshsh);

(3) Bicolor super sweet was a progeny with yellow-round kernels derived from a three-way cross ♀LAW x ♂(ULSS3 x Srikandi) which then was selfed and selected for yellow-round kernels (a mixture of genotypes CCShSh, CcShSh, and CcShsh);

(4) LAS Y-r sugary was a progeny with yellow-wrinkle kernels derived from the cross of ♀Srikandi X ♂ULSS3 which then was selfed and selected for yellow-wrinkle kernels (genotype CC susu).

Research plots were fertilized with urea, SP36, and KCl each at a dose of 400, 200 and 200 kg ha^{-1}, respectively, in strip application. Basal fertilizers were applied on the 7th day after planting (dap) in forms of a half dose of urea and full dose of SP36 and KCl; the second application of urea was given at 30 dap. To differentiate cultivars, planting rows were applied with agri-cultural-lime (71.5% Ca), dolomite (16.4% Ca + 9.99% Mg), Portland cement (34.5% Ca + 20.9% Mg), and a mixture of 3 aglime: 2 dolomite on 7th day before planting. Other materials applied were insecticide Marshal (carbosulfan, seed treatment) 10 g kg^{-1} kernels, Furadan 3G (carbofuran, insecticide) 2 kg ha^{-1} and Roundup (glyphosate, herbicide) 2 l ha^{-1}.

Planting space was 20 cm within-row X 70 cm between-rows in a one-plant hill (planting density of 74,100 plants ha^{-1}) following a split-plot design with two replicates. Main plots were the screening of cultivars based on three doses of Ca-Mg: 0, 200 and 400 kg ha^{-1}of the sources: aglime, dolomite, Portland cement and the mixture 3 aglime: 2 dolomite. Subplots were four parental populations (cultivars).

Data was averaged to construct descriptive analyses of characters of interest to be compared with those of the commercial standard. The characters of interest involved plant height (cm), leaf numbers, leaf greenness value as determined by a chlorophyll-meter, male-flower spike numbers, ear position (% plant height), ear length (cm), ear diameter (cm), kernel-rows ear^{-1}, kernel sucrose-content at 16 days after pollination (dap) (% ^{0}Brix as determined by a hand-held refractometer). The descriptive analysis gave information of improvement needed before the cultivars were reported for national release.

Data was then analyzed for variance differences. Analyses of variances were employed to reveal the effects of Ca-Mg, cultivars and the interaction of Ca-Mg X cultivar. Tukey's $HSD_{0.05}$ was employed to rank the effectiveness of kind and dose of Ca-Mg treatments to find the kind and dose best as a screening medium in selecting the cultivars. Tukey's $HSD_{0.05}$ was also employed to rank the cultivars.

The means squares in the analysis of variance were used to predict the values of genetic variance (σ^2g), broad-sense heritability (h^2_{BS}), and genetic coefficient of variation (CVg) for the characters of interest. Table of analysis of variance used to predict the expected mean-squares and was constructed following Hallauer *et al*., (2010) (Table 1).

Table 1. The analysis of variance table with expected mean-squares

Source of Variation	Df	Mean Square	Expected Mean Square
Replicate	(r – 1)		
Kind of Ca-Mg	(c – 1)		
Error a	(r – 1)(c – 1)	MS_4	
Cultivar	(g – 1)	MS_3	$\sigma^2 + r\sigma^2cg + rc\sigma^2g$
Ca-Mg X Cultivar	(c – 1) (g – 1)	MS_2	$\sigma^2 + r\sigma^2cg$
Error b	c(g – 1)(r – 1)	MS_1	σ^2
Total	rcg – 1		
CVa %		$\sqrt{MS_4}/\bar{X}$	
CVb %		$\sqrt{MS_1}/\bar{X}$	

Hence, genetic variation (σ^2g) was calculated as:

$\sigma^2g = (MS_3 – MS_2)/rc$ ±

$s.e.\sigma^2g = \sqrt{(2/(rc)^2} \text{ X } [\{MS_3^2/(df_2+2) + MS_2^2/(df_3+2)\}]$

and declare that $\sigma^2g > 0$ if >s.e. σ^2g

and broad-sense heritability (h^2_{BS}) as:

h^2_{BS} % $= \{\sigma^2g/ (\sigma^2/rc+\sigma^2cg/c + \sigma^2g)\}$ X 100 % ±

$s.e.h^2_{BS}=\{s.e.\ \sigma^2g/ (\sigma^2/rc+\sigma^2cg/c + \sigma^2g)\}$ X 100 %; with

$\sigma^2cg = (MS_2 – MS_1)/r$

and declare that $h^2_{BS} > 0$ if $h^2_{BS} >$ s.e. h^2_{BS}

and genetic coefficient of variation (CVg) as:

$CVg = (\sqrt{\sigma^2g}/\bar{X})$ X 100%

Table 2. Descriptive analyses of the characters of interest ($\overline{X}$ ± standard error of means) as compared to the commercial standard

Cultivars	**Plant height (cm)**	**Leaf numbers**	**Leaf greenness (SPAD)**	**Male spike numbers**	**Ear position (% plant height)**	**Ear length (cm)**	**Ear diameter (cm)**	**Kernel-rows.ear^{-1}**	**Kernel sucrose-content at 16 dap (% ^{0}Brix)**
LASS Y-R	126.50± 3.70	12.80±1.00	40.45±2.41	13.50±2.10	50.67±6.10	16.50±0.17	3.61±0.33	11.33±0.00	18.79±0.23
LASS Y-w	110.46± 4.79	12.91±0.58	43.29±4.29	12.21±0.46	49.52±0.12	17.17±0.50	3.57±0.01	11.66±0.33	22.75±0.93
Bicolor	127.10±21.60	12.92±0.67	42.13±2.73	12.07±1.27	49.89±0.91	16.17±1.50	3.32±0.16	11.00±1.67	18.79±0.23
LAS Y-w	116.00±33.00	11.70±1.30	45.24±0.46	7.90±3.70	44.27±9.58	14.50±5.83	3.23±1.04	12.66±0.66	24.62±3.73
Commercial standard	≥ 150	13 – 15	44.0 – 48.0	≤15	± 48	≥ 16	≥ 4.50	14 - 16	16

Remarks: SPAD was index as measured by the chlorophyll meter apparatus

Table 3. Mean square and coefficient of variation (CV) compiled from analyses of variances for all characters of interest

Source of Variation	**Df**	**Mean Square**								
		Plant height	**Leaf numbers**	**Leaf greenness**	**Male spike numbers**	**Ear position**	**Ear length**	**Ear diameter**	**Kernel-rows.ear^{-1}**	**Kernel sucrose-content at 16 dap**
Replicate	1	0.600	1.670	2.282	43.200*	214.830	0.160	0.754	0.531	1.431
Kinds of Ca-Mg	11	1414.000*	2.781**	37.304	22.610*	52.600	13.230*	1.031*	1.019	62.514**
Error a	11	435.700	0.376	14.570	5.770	47.860	3.350	0.442	1.803	5.007
Cultivar	3	23.600	2.302*	8.967	4.100	67.090	0.620	1.064	2.100	3.704
Ca-Mg x Cultivar	33	245.900	0.698	16.136*	8.130	30.450	6.490	0.506	1.745*	5.128
Error b	36	345.200	1.100	8.140	13.130	67.880	12.210	0.502	0.844	4.844
CVa (%)		16.224	5.126	8.209	17.908	14.858	10.602	18.494	11.256	9.740
CVb (%)		14.441	8.768	6.136	27.014	17.694	20.240	19.705	7.703	9.580

Remarks: * significantly different at p≤ 0.05; ** significantly different at p≤ 0.01

RESULTS AND DISCUSSION

The Phenotypes of Characters of Interest

The nine characters of interest analyzed: plant height, ear diameter, and kernel-rows.ear^{-1} were yet to comply with a commercial standard (Table 2). In relation to that the parental populations were of S_3 (self-3) generation, the decrease of performance may be caused by an inbreeding depression (Hikam *et al*., 2008). The true-type (wrinkle-kernel) sweet corn may experience inbreeding depression relatively quick due to the fact that the wrinkle of kernels is controlled by recessive-homozygous genes (susu, sese, or shsh). Since markets were generally supplied with the true-type sweet corn, the wrinkle of kernels was maintained to preserve a level of sweetness at ≥ 16 % of sucrose content in immature kernels 16 dap. Learning from the values of standard errors of the three characters of interest, crosses are needed to eliminate the inbreeding depression.

Analysis of Variance for the Characters of Interest

Table 3 indicated that as a screening media, the kinds of Ca-Mg were more effective than cultivars; and the interaction of those two was significant on the leaf greenness and the kernel-rows.ear^{-1}. The interaction of kinds of Ca-Mg X cultivars indicated a probability to improve the leaf greenness and the kernel-rows.ear^{-1} through Ca-Mg application.

Coefficient of variance b (CVb) was value-able to inform the importance of genetic effect as comparation to the importance of environ-ment (Hikam *et al.*, 2008). It is assumed that if CVb≤ 10 % for a character of interest indicates the effect of genetic > environment and the effect of environment control the character may be ignored. On the other hand, if CVb ≥ 10 %, the effect of environment cannot be disregarded.

As a consequence, the improvement of kernel-row.ear^{-1} through crosses may be easier to accomplish than the improvement of plant height or ear diameter. However, it is expected that the ear diameter will concomitantly increase with the increase of kernel-rows.ear^{-1} as long as the seed size (g.100 kernels^{-1}) can be maintained.

Rank of Effectiveness of Kind and Dose of Ca-Mg as the Screening Media

The kinds of Ca-Mg applied in this research: aglime, Portland cement, dolomite, and the mixture of 3 aglime: 2 dolomite; each at a dose of 0, 200, and 400 kg.ha^{-1}indicated that all kinds of Ca-Mg were effective as screening environ-ment (Table 4). However, two parameters: ear position and kernel rows.ear^{-1} showed no differences indicating the kind and dose of Ca-Mg applied did not screen to those parameters. Ear position has been selected as to be about in half-way, or 50 % of plant height, and the sub-sequent effect of selecting for greater size (Hikam, 2007). Ear position was somewhat close to the commercial expectation (48 – 52 % of plant height) but kernel rows.ear-1, around 12 rows, became lagged behind the commercial expectation for 16 rows.

Aglime 400 was the best kind and dose of Ca-Mg to screen for the environment followed by cement 400, dolomite 200, and mixture 400. However on the dolomite, the dose of 0 and 200 kg.ha^{-1}was better than the dose of 400 kg.ha^{-1}. Apparently this anomaly should be related to the characteristics of the soil of Lampung RYP used in this research. The characteristic of low fertility and pH< 5.8 owned by a RYP soil may have caused the application of Ca-Mg to be more as a phosphate binder and pH neutralizer than as a nutritive element (Hikam *et al*., 2008). However, Ca-Mg media were more effective than the cultivars as differentiating factor since the differences among cultivars did not exist (Table 3).

Table 4. Rank of effectiveness of kind and dose of Ca-Mg based on $HSD_{0.05}$ test

Kind and dose of Ca-Mg	**Plant height (cm)**	**Leaf numbers**	**Leaf greenness (SPAD)**	**Male spike numbers**	**Ear position (% plant height)**	**Ear length (cm)**	**Ear diameter (cm)**	**Kernel-rows. ear^{-1}**	**Kernel sucrose-content at 16dap (% ^{0}Brix)**	**Numbers of ‘a’ value**	**Rank**
Aglime 0	119.79abc	11.35b	48.39a	14.33ab	47.63	18.44ab	3.49ab	11.17	27.46a	6	2
Aglime 200	113.80bc	11.35b	46.95ab	14.25ab	45.94	17.43ab	3.34ab	11.92	25.48ab	5	3
Aglime 400	134.30abc	12.28ab	49.39a	15.53a	48.14	18.90a	3.86ab	12.00	28.16a	7	1
Dolomite 0	144.31ab	11.92ab	47.95a	15.49a	46.94	18.73a	3.71ab	12.18	21.49cd	6	2
Dolomite 200	132.45abc	11.68ab	46.19ab	14.09ab	44.49	16.29ab	3.47ab	12.06	21.34cd	6	2
Dolomite 400	142.95ab	11.35b	46.21ab	15.39a	45.54	18.89a	3.70ab	12.60	19.35d	5	3
Cement 0	134.50abc	11.73ab	47.56ab	11.07b	42.57	16.88ab	3.56ab	11.58	22.26bcd	5	3
Cement 200	123.43abc	11.47ab	47.11ab	12.61ab	44.13	15.61b	3.19b	11.92	20.18d	4	4
Cement 400	147.70a	12.35ab	48.12a	13.05ab	46.25	17.00ab	3.62ab	11.81	22.56bcd	6	2
Mixture 0	120.00abc	12.59ab	42.78b	11.42b	48.59	16.09ab	3.43ab	11.67	21.24cd	4	4
Mixture 200	103.19c	12.26ab	42.19ab	11.04b	45.92	15.59b	3.22b	12.17	21.82bcd	2	5
Mixture 400	127.48abc	13.23a	42.65b	12.71ab	52.59	17.63ab	4.55a	12.08	24.33abc	6	2
$HSD_{0.05}$	32.43	1.83	4.98	3.36	10.38	2.97	1.24	1.60	3.84		

Remarks: Number followed kind of Ca-Mg was the dose of application (kg ha^{-1}); mixture was the mixture of 3 aglime : 2 dolomite (w/w); same letter followed numbers in the same column showed no difference at $HSD_{0.05}$, the letter ‘a’ indicated the best response

The interaction between kind and dose of lime X cultivars expressed only for leaf greenness and leaf kernel-rows.ear^{-1}characters of interest as indicated by Table 5 and 6, respectively. The interaction for leaf greenness showed that only Mixed 400 X Bicolor and Mixed 400 X LAS Y-w assigned into 'b' category indicated that the rest of kinds and doses Ca-Mg: Aglime 200, Aglime 400, Dolomite 200, Dolomite 400, and Mixed 200 gave good response to leaf greenness of the cultivars (Table 5). The interaction which assigned 'a' and 'ab' categories gave leaf greenness 40.45 – 52.65 (Table 5).

The interaction of Aglime 0 X LAS Y-w indicated the best (52.65a) although the interaction value essentially was not different with all other interaction of zero application of lime as in Aglime 0 X cultivars, Dolomite 0 X cultivars, Cement 0 X cultivars, and Mixture 0 X cultivars. Furthermore, all lime X cultivar interactions essentially were not different except for the highest interaction (Aglime 0 X LAS Y-w, 52.65a) and the lowest (Mixture 400 X LASS Y-w,39.06b; and Mixture 400 X LAS Y-w, 39.19b). The finding indicated that the availability of Ca and Mg may not be directly responsible on the improvement of corn leaf greenness (Siddiqui *et al*., 2012). However, Gilliham *et al*., (2011) indicated the importance of apoplastic Ca in regulating symplastic water flow and stomata opening, thus maintaining cell turgor and leaf erectness. A Ca deficiency malformated the leaves to become smaller and fail to open (Hart *et al.*, 2010) although Mg^{2+} presented as the cation which bound to the center of pyrrole ring of the chlorophyll (Nelson and Cox, 2008). The leaf greenness was the result of the density and the activity of chlorophyll which were improved by the availability of N (Muñoz-Huerta *et al*., 2013).

The interaction of kernel-rows.ear^{-1} grouped the cultivars into three categories: a, b and c; for 'a' category grouped into 'a' and 'ab' categories which were not different. The interaction assigned into 'a' and 'ab' categories gave 11.67 – 13.67 kernel-rows.ear^{-1} (Table 6).

Data in Table 6 indicated that the interaction of Aglime 200 X LASS Y-R (13.00a), Aglime 200 X LASS Y-w (12.00ab); Dolomite 200 X LASS Y-R (13.25a), Dolomite 200 X Bicolor (12.60ab); and Mixture 400 X LASS Y-R (12.67a), Mixture 400 X Bicolor (13.00a) indicated that only two out of four cultivars treated with aglime and dolomite at 200 kg ha^{-1} responded great whereas other two cultivars responded lower. The finding concluded that aglime and dolomite at 200 kg ha^{-1} enabled to screened and differentiated cultivars into two categories.

Table 5. Kinds and dose of Ca-Mg X cultivar interaction for leaf greenness

Kind and Dose of Ca-Mg	**Cultivar**			
	LASS Y-R	**LASS Y-w**	**Bicolor**	**LAS Y-w**
Aglime 0	48.99ab	41.63ab	50.30ab	52.65a
Aglime 200	47.53ab	45.53ab	48.04ab	46.68ab
Aglime 400	51.29ab	47.18ab	48.87ab	49.75ab
Dolomite 0	47.03ab	47.93ab	48.46ab	48.38ab
Dolomite 200	45.84ab	46.50ab	45.90ab	46.50ab
Dolomite 400	42.91ab	49.07ab	46.27ab	46.60ab
Cement 0	49.80ab	47.08ab	47.47ab	45.87ab
Cement 200	44.49ab	45.46ab	49.98ab	48.50ab
Cement 400	48.18ab	46.60ab	46.10ab	48.50ab
Mixture 0	40.45ab	43.29ab	42.12ab	45.24ab
Mixture 200	40.58ab	42.87ab	51.01ab	43.95ab
Mixture 400	48.18ab	44.16ab	39.06b	39.19b
$HSD_{0.05}$	3.15			

Remarks: Number followed kind of Ca-Mg was the dose of application (kg ha^{-1}); mixture was the mixture of 3 aglime: 2 dolomite (w/w); same letter followed numbers in the same column showed no difference at $HSD_{0.05}$, the letter 'a' indicated the best response

Table 6. Kinds and dose of Ca-Mg X cultivar interaction for kernel-rows.ear^{-1}

Kind and Dose of Ca-Mg	Cultivar			
	LASS Y-R	**LASS Y-w**	**Bicolor**	**LAS Y-w**
Aglime 0	10.33c	10.00c	11.00c	13.33a
Aglime 200	13.00a	12.00ab	11.67bc	11.00c
Aglime 400	11.00c	12.00ab	13.67a	11.33bc
Dolomite 0	12.67a	10.97c	13.37a	11.70ab
Dolomite 200	13.25a	11.08bc	12.60ab	11.30bc
Dolomite 400	12.13ab	12.97a	12.00ab	13.30a
Cement 0	12.00ab	11.20bc	11.60ab	11.50ab
Cement 200	11.87ab	11.45bc	12.60ab	11.75ab
Cement 400	10.60bc	11.80ab	12.60ab	12.25ab
Mixture 0	11.33bc	11.67ab	11.00c	12.67a
Mixture 200	12.33ab	11.67ab	11.00c	13.67a
Mixture 400	12.67a	11.33bc	13.00a	11.33bc
$HSD_{0.05}$	1.05			

Remarks: Number followed kind of Ca-Mg was the dose of application (kg ha^{-1}); mixture was the mixture of 3 aglime: 2 dolomite (w/w); same letter followed numbers in the same column showed no difference at $HSD_{0.05}$, the letter 'a' indicated the best response.

Furthermore data in Table 6 showed that the interaction of Cement 400 X LASS Y-w (11.80ab), Cement 400 X Bicolor (12.60ab), Cement 400 X LAS Y-w (12.25ab); Mixture 200 X LASS Y-R (12.33ab), and Mixture 200 X LASS Y-w (11.67ab), Mixture 200 X LAS Y-w (13.67a) indicated that the doses of cement and mixture enabled to screen and differentiate cultivars also into two categories although with less power.

Finally, data in Table 6 indicated that the interactions of Dolomite 400 X cultivar indicated the best which gave 'a and ab' to all interactions Dolomite 400 X LASS Y-R (12.13ab), Dolomite 400 X LASS Y-w (12.97a), Dolomite 400 X Bicolor (12.00ab), and Dolomite 400 X LAS Y-w (13.30a). However, the interaction of Dolomite 400 X cultivar lost their capability to screen and differentiate cultivars.

Rank of Effectiveness of Cultivar Hybridization

Table 3 and Table 7 showed that the four true-type cultivars tested in this research were not different one to another. In a cross-breeding program resulting F_1-hybrid, meant that good parent X good parent resulted good F_1-hybrid progeny (Hallauer *et al*., 2010).

Table 7 indicated that the F_1-hybrid progenies as resulted from the breeding program was acceptable as commercials sweet corn for characters of interest: leaf numbers (11.96 leaves plant^{-1}), leaf greenness (46.50 SPAD index), male-spike numbers (13.41spikes.plant^{-1}), ear position (46.53% of plant height), ear length (17.26 cm), and sucrose content of young kernels (22.97 % ^{0}Brix). However, the characters of interest: plant height (128.65 cm< 150 cm), ear diameter (3.59 cm < 4.5 cm), and kernel-row.ear^{-1} (11.93< 14) were below commercial standard for sweet corn. For those three characters, they may have to be introduced to control genes from outside of the populations. The introduced controlling-genes can be from related genotypes (segregating-type cultivars) or from non-sweet (feed) corn as it was accomplished by Hikam (2007) in the development of LASS sweet corn.

Table 7. Rank of effectiveness of the cultivar based on $HSD_{0.05}$ test

Cultivar	Plant height (cm)	Leaf numbers	Leaf greenness (SPAD)	Male spike numbers	Ear position (% plant height)
LASS Y-R	129.850	12.160	46.597	14.024	47.259
LASS Y-w	127.976	12.276	45.609	13.263	48.284
Bicolor	129.850	11.610	46.966	13.110	44.350
LAS Y-w	127.714	11.800	46.817	13.258	46.358
$HSD_{0.05}$	14.446	0.813	2.218	2.817	6.405

Table 7. (continued)

Cultivar	Ear length (cm)	Ear diameter (cm)	Kernel-rows.ear^{-1}	Kernel sucrose-content at 16 dap (% ^{0}Brix)	Number of 'a'value	Rank
LASS Y-R	17.179	3.910	11.931	23.309	9	1
LASS Y-w	17.482	3.472	11.511	23.318	9	1
Bicolor	17.114	3.483	12.175	22.629	9	1
LAS Y-w	17.281	3.515	12.094	22.637	9	1
$HSD_{0.05}$	2.717	0.551	0.714	1.711		

Remarks: Since all cultivar showed no differences at $HSD_{0.05}$, the number of 'a' values added to 9 folowing the numbers of parameters analyzed to simplify their rank determination.

Analyses of Genetic Variation, Broad-Sense Heritability and Genetic Coefficient of Variation

Only the character of interest: leaf numbers indicated genetic variation ($\sigma^2 g$) and broad-sense heritability (h^2_{BS}) > 0 (> 1X standard error se; Table 8). The data indicated that the four true-type cultivars: LASS Yellow-Round, LASS Yellow-wrinkle, Bicolor, and LAS Yellow-wrinkle were essentially genetic identical. The data were supported by the genetic coefficient of variation (CVg) value < 5 % indicating that the control of characters of interest was genetic and the effects of environment may be disregarded.

The genetic identical of the four true-type cultivars followed the identical by descent (Hallauer *et al*., 2010) inherited from the female common parent ULSS3 line in the beginning of their development. Therefore the four true-type cultivars were half-sib related. The genetic identical was not beneficial for the F1-hybrid cross program since it may response similar to a self program which increase homozygosity. In order to increase the measurements of characters of interest, parental lines will have to be reciprocally crossed inter-parental or to outside genetic source for a heterotic effect (Hallauer *et al*., 2010). The mean analyses for the characters of interest ($\overline{X}$, Table 8) showed the values of satisfaction of the breeding program. There were three characters of interest needed to be improved to fulfill the commercial standard: (1) plant height (from 128.65 to ≥ 150.0 cm); (2) ear diameter (from 3.59 to ≥ 4.5 cm); and (3) kernel rows.ear^{-1} (from 11.93 to ≥ 14.0 rows).

Although characters: plant height, ear diameter, and kernel rows.ear^{-1} needed to be improved the genetic variation and broad-sense heritability values for those characters were essentially zero (Table 8). Hence, it would need genes from the outside populations for subsequent improvement programs (Hikam, 2007).

CONCLUSION AND SUGGESTION

The application of Ca-Mg was useful as selection factor to modify plant environment. The application of Ca-Mg also improved sweet corn growth; aglime 400 kg ha^{-1} was the best followed by Portland cement 400, dolomite 200 and aglime-dolomite mixture 400 kg ha^{-1}. The interactions of dose and kind of Ca-Mg X cultivar expressed for leaf greenness and kernel-row.ear^{-1} with the interactions for kernel-row.ear^{-1} was more meaningful.

Table 8. Genetic variance ($\sigma^2 g$), broad-sense heritability (h^2_{BS}), and genetic coefficient of variation (CVg) for the characters of interest

Variables	Variance components							
	$\sigma^2 g$	±	se $\sigma^2 g$	h^2_{BS} (%)	±	se h^2_{BS}	CVg (%)	$\bar{X}$
Plant height	0	±		0	±		0	126.65 cm
Leaf numbers	0.067*	±	0.061	39.122*	±	35.743	2.161	11.96
Leaf greenness	0			0			0	46.50 SPAD
Male spike numbers	0			0			0	13.41
Ear position	1.527	±	1.794	22.150	±	26.025	2.654	46.53 %
Ear length	0			0			0	17.26 cm
Ear diameter	0.023	±	0.028	26.931	±	32.998	0.119	3.59 cm
Kernel-row.ear^{-1}	0.015	±	0.058	7.571	±	29.689	0.095	11.93
Kernel sucrose-content at 16 dap	0			0			0	22.97 %

Remarks: * indicated that $\sigma^2 g$ and h^2BS values were not zero since they were > 1X se (standard error)

Further analysis showed that the differences among cultivars did not exist and the characters of interest of the cultivars complied with those of commercial standard for the sweet corn. Although characters: plant height, ear diameter, and kernel rows.ear^{-1} needed to be improved the genetic variation and broad-sense heritability values for those characters were essentially zero. Hence, it would need genes from the outside populations for subsequent the improvement programs.

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