Kasetsart J. (Nat. Sci.) 40 : 289 - 296 (2006)

Development of Sweet Corn Inbred Lines by Family Selection under Different Competition Environments

Nguyen Tien Truong and Krisda Samphantharak*

ABSTRACT

Sweet corn (*Zea mays* L.) breeding has focused on quality and agronomic traits with yield performance as second priority trait. The objective of the present study was to compare yield and to combine ability of sweet corn inbred lines selected from 3 original single crossed under different competition environments; firstly, under high plant density (0.75 × 0.25 m); secondly, under low – competition spacing (0.866 m) in non – replicated honeycomb design; and thirdly, by alternate selection between the first 2 methods. The resulted 9 S3 family lines from each original hybrids were grouped into three line groups, totaling of 9 groups. Diallel cross was performed within each group, resulting in 27 intra – family hybrids. Simultaneously, they were crossed to a single cross, Insee2 to form 27 testcross hybrids.

The results of the study showed that sweet corn inbred lines derived from selection under low – competition environment by honeycomb selection had not only higher yield but also higher combining ability compared with inbred lines derived from selection under high plant density environment and alternate selection between the first two methods. However, different sources of germplasm responded differently to the common tester.

Key words: sweet corn, inbred line, family selection, competition environment, honeycomb selection design, low – competition environment

INTRODUCTION

The most often used plant breeding method for inbred line development in maize is the pedigree method. It provides the detail of record that shows family relationship. Besides an appropriate breeding method, genetic variability, environment under plant selection and accuracy of data collection are equally important. However, recent research information presented by Rasmusson and Phillips (1997) in barley and Troyer (1999) in corn suggested that continuously used of related lines as parents for inbred improvement not only extended life time of useful inbreds but also effectively kept most of useful traits for new generations of inbreds and hybrids. Nevertheless, selection method must discriminate true genotypic expression from interaction between genetics and internments. Troyer and Rosenbrook (1983) selected corn inbreds under high plant density than normal planting density, aiming to obtain inbreds of which could tolerate to environmental stress. The resulted inbred lines were low yield per plant but gave high yield per area under high plant density condition. The selection method may be useful when combine

Department of Agronomy, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand.
Corresponding author, e-mail : agrkrs@ku.ac.th

Received date : 08/08/05 Accepted date : 16/02/06

harvesting machine is available provided that high production input is feasible. Conversely, Fasoula and Fasoula (2002) collectively provided research information to prove that plant selection under nil – competition was very effective for genetic expression, gaining high yield per plant inbreds and density – independent hybrids in maize.

In order to find out the effectiveness of the above suggested selection methods and utilization of breeding materials, plant selection were conducted under high plant density, low – competition and combining both methods. Relatively narrow genetic base lines were used to start the program, recovered hybrids and testcross hybrids were performed to compare the effectiveness of breeding materials in new hybrid combinations.

MATERIALS AND METHODS

Five S_7; $Agsh_2$– 201, $Agsh_2$– 302, $Agsh_2$– 303, $Agsh_2$– 309 and $Agsh_2$ – 318 from sweet corn breeding program of Department of Agronomy, Kasetsart University were crossed in diallel fashion. The resulted 10 single crosses were subjected to 4 replications of strip test under normal planting conditions and the top – 3 single crosses; $Agsh_2$– 201/309, $Agsh_2$– 303/309 and $Agsh_2$– 201/318 were selected and selfed to obtain S_1 ears. Nine S_1 ears of each family were separated into 3 sets, each set composed of 3 ears and summed up to 9 sets of S_1 lines from 3 families. Each set of each family was planted in each of 3 selection environments; high plant density (HD) (0.75 × 0.25 m), low competition (0.866 m) in non-replicated honeycomb design (HC) and alternate environments (HC – HD). Three plants within each line were selfed and bulked to obtain 27 S_2 lines. The resulted 27 S_2 lines were continued to be planted in 3 different environments as designed and selfed to obtain 27 S_3 lines.

Each of 27 S_3 line was devided into 2 groups and both were planted as designed. The first group was selfed to obtain 27 S_4 lines; 9 S_4 lines from HD – HD – HD – HD (L_1 to L_9), 9 S_4 lines from HC – HC – HC – HC (L_{19} to L_{27}) and 9 S_4 lines from HC – HD – HC – HD (L_{10} to L_{18}). Simultaneously, the S_3 lines of the first group were crossed to the single cross tester (Insee – 2 hybrid) to obtain 27 testcross hybrids. Three S_3 lines in each set of the second group were dialleled to form 3 intra – set hybrid (recovered hybrid) per set, total of 27 intra – set hybrids, 9 from each selection environment.

Twenty seven testcross hybrids, 27 recovered hybrids and 27 S_4 lines were separately tested in adjacent areas using randomized complete block design (RCBD) with 4 replications, 3 row plots of 5 m long and 0.75 × 0.25 m plant spacing. The 3 original single cross hybrids $Agsh_2$ – 201/309, $Agsh_2$ – 303/309 and $Agsh_2$ – 201/318 were included as common checks for all trials.

All hybrids were tested for their green ear and marketable yield as well as major agronomic and quality traits for commercial sweet corn hybrid. Yield data were collected from the central rows and 5 plants in the border rows of each hybrid were selfed and harvested separately to evaluate quality traits. The S4 lines were tested for seed yield to evaluate their potential use as parents in hybrid seed production.

All experiments were conducted from the year 2003 to 2005 at National Corn and Sorghum Research Center, Suwan Farm, Nakhon Ratchasima province, Thailand.

RESULTS AND DISCUSSION

Sweet corn is consumed as fresh market and processed vegetable. It value depends very much on the quality of products. Therefore, single cross hybrids which give the highest uniformity and quality are necessary for high end market. However, weak inbred lines of sweet corn is one of the major obstacle in commercial hybrid seed production, especially single cross seed production. Selection method for the effectiveness of selection for high yield and tolerance to environmental stress inbreds is still a matter of discussion (Troyer, 1999; Fasoula and Fasoula, 2002). Data presented in Table 1 hinted into certain extent of difference between selection methods under study. Considering the grand mean of inbreds under different methods of selection, inbred selection under low competition in non – replicated honeycomb design (HC) gave the highest average grain yield followed by alternate environments (HC – HD) and selection under high plant density (HD). Individually, each had three inbred lines; S_4L_{21}, S_4L_{24} and S_4L_{25} from HC and one inbred line S_4L_{17} from HC – HD which gave significantly higher yield than the less of inbreds and the highest yield check, $Agsh_2$ – 201. This finding was in agreement with Fasoula and Fasoula (1997) which collectively piled up data to show that in the absence of competition, single plant heritability was optimized, phenotypic expression and differentiation were maximized and hence facilitated single plant selection for performance per se. However, there were several inbreds from each selection method which gave higher yield than the original inbreds, $Agsh_2$ – 303, $Agsh_2$ – 309 and $Agsh^2$ – 318. Since original inbred lines used in this study were genetically related, the results of this study as so supported the evidences presented by Rasmusson and Philips (1997) and Troyer (1999) who found that inbred lines could be improved by crossing between related parental inbred lines. Since all inbred parents were highly selected for kernel quality and therefore selection for new inbred lines could concentrate only on yielding ability of new inbred lines.

Green ear and marketable yields of the 27 intra – family and the 3 original hybrids are presented in Table 2. The intra – family hybrid, L_{25}/L_{27} gave significant higher yield than the original hybrid, $Agsh_2$ – 201/318 and both inbred lines were selected from HC. The result indicated a very strong additive gene effect in this cross. The data also supported the results presented by Tokatlidis *et al*. (1998) and Tokatlidis *et al*. (2001) in corn. However, none of intra – family hybrid from original hybrids, $Agsh_2$ – 201/309 and $Agsh_2$ – 303/309 gave an excess green ear yield than the original hybrids. Infact, they gave significantly lower yield than the original hybrids. The different response to selection among the three origal hybrids might result from the difference in breeding materials. Both parent lines of $Agsh_2$ – 201/318 were high yield inbred lines which presumedly accumulated more additive genes and hence transmitted high yielding ability more effectively into the intra – family hybrids. In contrast, $Agsh_2$ – 201/309 and $Agsh_2$ – 303/309 were from either one or two low yield inbred lines and thus accumulated more non – additive gene effect and resulted in inbreeding depression in the intra – family hybrids. Moreover, most of intra – family hybrids from these two original sources gave lower percentage of marketable yield than the corresponding original hybrid.

To evaluate combining ability of inbred lines, a single cross hybrid (Insee – 2) was used as tester. Green ear and marketable yield of the 27 testcross hybrids are presented in Table 3. There were 13 and 17 testcross hybrids which gave higher but not significantly different green ear yield than Agsh2 – 201/309 and Agsh2 – 303/309, respectively. Twenty – four testcross hybrids were significantly higher in green ear yield than Agsh2 – 201/318. The higher average as well as the top testcross hybrids from each original source came from inbreds selected under low competition environment in honeycomb design. They also tended to have higher percentage of marketable yield than hybrids from the other two selection methods.

Moreover, the top – 10 testcross hybrids presented in Table 4 showed that five out of ten hybrids were derived from inbreds selected under low competition in honeycomb design, especially the top – 4 hybrids. Another four hybrids were from inbreds selected under high density environment and the only one was from alternate selection. The results indicated that inbred lines extracted under low competition not only had

Table 1 Grain yields at 15 percent moisture of S_4 lines from three selection methods planted at Suwan Farm in January, 2005 (dry season).

	Inbred lines extracted from $Agsh_2$–201/309			Inbred lines extracted from $Agsh_2$–303/309			Inbred lines extracted from $Agsh_2$–201/318		
	S_4 line	Yield (ton/ha)	Shelling percentage	S_4 line	Yield (ton/ha)	Shelling percentage	S_4 line	Yield (ton/ha) percentage	Shelling
HD	S_4L1	$0.693^{e\text{-}g}$	52.6	S_4L4	$0.815^{b\text{-}d}$	60.0	S_4L7	$0.817^{b\text{-}d}$	52.4
	S_4L2	$0.697^{e\text{-}g}$	58.1	S_4L5	$0.\ 543^{h\text{-}j}$	48.7	S_4L8	0.896^{b}	64.0
	S_4L3	$0.550^{h\text{-}j}$	45.9	S_4L6	0.425^{k}	49.5	S_4L9	0.840^{bc}	59.3
	Average	***0.647***	***52.2***	***Average***	***0.594***	***52.7***	***Average***	***0.851* X = *0.697***	***59.9***
HC	S_4L19	$0.651^{f\text{-}i}$	54.5	S_4L22	0.852^{bc}	61.3	S_4L25	1.024^{a}	51.9
	S_4L20	$0.548^{h\text{-}j}$	57.8	S_4L23	$0.\ 402^{k}$	56.9	S_4L26	0.868^{be}	54.6
	S_4L21	1.104^{a}	63.2	S_4L24	1.072^{a}	66.4	S_4L27	0.841^{bc}	55.8
	Average	***0.768***	***58.8***	***Average***	***0.781***	***61.5***	***Average***	***0.911* X = *0.820***	***54.1***
(HC – HD)	S_4L10	$0.658^{f\text{-}h}$	64.7	S_4L13	0.503^{jk}	46.4	S_4L16	$0.596^{g\text{-}j}$	45.7
	S_4L11	$0710^{d\text{-}g}$	61.1	S_4L14	$0.\ 686^{e\text{-}g}$	55.8	S_4L17	1.043^{a}	56.2
	S_4L12	$0.565^{h\text{-}j}$	58.3	S_4L15	0.895^{b}	54.9	S_4L18	0.846^{bc}	59.5
	Average	***0.644***	***61.3***	***Average***	***0.595***	***52.4***	***Average***	***0.828* X = *0.722***	***53.8***

$Agsh_2$ – 201 (check 1): $0.788^{b\text{-}e}$ with 61.7% shelling percentage
$Agsh_2$ – 303 (check 2): $0.626^{f\text{-}i}$ with 55.2% shelling percentage
$Agsh_2$ –309 (check 3): $0.532^{i\text{-}k}$ with 61.1% shelling percentage
$Agsh_2$ –318 (check 4): $0.746^{c\text{-}f}$ with 47.2% shelling percentage

Table 2 Green ear and marketable yields of intra – family hybrids (S_3 x S_3) planted at Suwan Farm in January, 2005 (dry season).

	Parents extracted from $Agsh_2$ – 201/309				Parents extracted from $Agsh_2$ – 303/309				Parents extracted from $Agsh_2$ – 201/318			
	Hybrid	Green yield (ton/ha)	Marketable yield (too/ha)	% of marketable yield	Hybrid	Green yield (ton/ha)	Marketable yield (too/ha)	% of marketable yield	Hybrid	Green yield (ton/ha)	Marketable yield (too/ha)	% of marketable yield
HD	L1/L2	8.73^{k}	4.47^{h}	51.2	L4/L5	10.47^{g-k}	7.46^{f}	71.3	L7/L8	14.27^{bc}	9.63^{bc}	67.5
	L1/L3	12.27^{c-g}	8.08^{d-f}	65.9	L4/L6	11.20^{d-j}	7.34^{f}	65.5	L7/L9	13.33^{cd}	8.49^{c-f}	63.7
	L2/L3	10.57^{f-k}	7.29^{f}	69.0	L5/L6	11.40^{d-j}	7.70^{ef}	67.5	L8/L9	13.40^{cd}	7.92^{ef}	59.1
	Average	**10.52**	**6.61**	**62.0**	**Average**	**11.62**	**7.50**	**68.1**	**Average**	**13.67**	**8.68**	**63.4**
HC	L19/L20	13.02^{e-f}	9.27^{b-d}	71.2	L22/L23	11.60^{d-i}	8.43^{d-f}	72.7	L25/L26	12.93^{c-g}	8.71^{c-e}	67.4
	L19/L32	10.73^{e-k}	7.87^{ef}	73.7	L22/L24	11.48^{d-i}	8.28^{d-f}	72.1	L25/L27	17.07^{a}	10.09^{b}	59.1
	L20/L21	9.33^{i-k}	4.99^{gh}	53.5	L23/L24	10.70^{e-k}	7.66^{ef}	71.6	L26/L27	12.67^{c-g}	8.21^{d-f}	64.8
	Average	**11.01**	**7.38**	**66.1**	**Average**	**11.26**	**8.12**	**72.1**	**Average**	**14.22**	**9.00**	**63.8**
(HC – HD)	L10/L11	11.27^{d-j}	6.03^{g}	53.5	L13/L14	10.81^{e-k}	7.85^{ei}	72.6	L16/L17	8.99^{k}	6.09^{g}	67.7
	L10/L12	11.86^{c-h}	8.36^{d-f}	70.5	L13/L15	13.20^{c-e}	8.74^{c-e}	66.2	L16/L18	13.20^{c-e}	7.37^{f}	55.8
	L11/L12	9.73^{h-k}	4.99^{gh}	51.3	L14/L15	12.34^{c-g}	8.35^{d-f}	67.7	L17/L18	12.60^{c-g}	8.01^{ef}	63.6
	Average	**10.95**	**6.46**	**58.4**	**Average**	**12.12**	**8.31**	**68.8**	**Average**	**11.60**	**7.16**	**62.4**
Check	Agsh2-201/309	16.13^{ab}	11.39^{a}	7.06	Agsh2-303/309	16.20^{ab}	11.49^{a}	70.9	Agsh2-201-318	13.07^{c-e}	9.25^{b-d}	70.8

Table 3 Green ear and marketable yields of testcross hybrids (Insee 2 x S_3) planted at Suwan Farm in January, 2005 (dry season).

	Parents extracted from $Agsh_2$ – 201/309				Parents extracted from $Agsh_2$ – 303/309				Parents extracted from $Agsh_2$ – 201/318			
	Hybrid	Green yield (ton/ha)	Marketable yield (too/ha)	% of marketable yield	Hybrid	Green yield (ton/ha)	Marketable yield (too/ha)	% of marketable yield	Hybrid	Green yield (ton/ha)	Marketable yield (too/ha)	% of marketable yield
HD	Insee2/L1	15.47^{b-f}	8.80^{h-k}	56.9	Insee2/L4	16.20^{b-f}	11.30^{a-e}	69.8	Insee2/L7	14.40^{d-g}	9.42^{f-j}	65.4
	Insee2/L2	18.53^{a-c}	11.28^{a-e}	60.9	Insee2/L5	16.73^{a-e}	11.94^{a-d}	71.4	Insee2/L8	15.80^{b-f}	8.69^{i-k}	55.0
	Insee2/L3	14.80^{d-f}	10.50^{d-g}	70.9	Insee2/L6	17.07^{a-e}	11.32^{a-e}	66.3	Insee2/L9	16.47^{a-f}	8.42^{jk}	51.1
	Average	16.27	10.19	62.9	Average	16.67	11.52	69.2	Average	15.56	8.84	57.2
HC	Insee2/L19	15.47^{b-f}	10.10^{e-i}	65.3	Insee2/L22	17.40^{a-d}	12.27^{a-c}	70.5	Insee2/L25	14.80^{d-f}	8.96^{g-k}	60.5
	Insee2/L20	18.93^{ab}	12.38^{ab}	65.4	Insee2/L23	15.20^{c-f}	10.45^{d-g}	68.8	Insee2/L26	18.54^{a-c}	11.55^{a-e}	62.3
	Insee2/L21	16.27^{b-f}	10.18^{e-i}	62.6	Insee2/L24	18.80^{ab}	12.66^{a}	67.3	Insee2/L27	20.00^{a}	12.19^{a-c}	61.0
	Average	16.89	10.89	64.4	Average	17.13	11.79	68.9	Average	17.78	10.90	61.3
(HC – HD)	Insee2/L10	14.93^{d-f}	8.98^{g-k}	60.1	Insee2/L13	18.54^{a-c}	11.25^{a-e}	60.7	Insee2/L16	17.53^{a-d}	9.53^{f-j}	54.4
	Insee2/L11	18.87^{ab}	10.29^{e-h}	54.5	Insee2/L14	17.34^{a-d}	10.88^{b-f}	62.7	Insee2/L17	16.54^{a-f}	10.80^{c-f}	65.3
	Insee2/L12	13.67^{e-g}	8.28^{jk}	60.6	Insee2/L15	13.13^{fg}	7.78^{k}	59.3	Insee2/L18	17.20^{a-e}	10.42^{d-g}	60.6
	Average	15.82	9.18	58.4	Average	16.34	9.97	60.9	Average	17.09	10.25	60.1
Check	Agsh2-201/309	16.64^{a-f}	10.52^{d-f}63.2		Agsh2-303/309$16.20^{b-f}$	11.34^{a-e}70.0	Agsh2-201-318		11.34^{g}	7.52^{k}	66.3	

Table 4 Some agronomic and quality traits of top 10 marketable yield hybrids from different sets of crosses, planted at Suwan Farm in January, 2005 (dry season).

Rank order	Hybrid	Green Yield	Marketable yield	Far length	Tipfill	Blanktip	Diameter Long	Seed Number	Row	Sweetness
		t/ha		cm						%
1	Insee2/L_{24}	18.80^{a-c}	12.66^{a}	19.40	17.70	1.70	4.33	0.87	13.60	14.0
2	Insee2/L_{20}	18.93^{ab}	12.38^{ab}	19.80	17.40	2.40	4.30	0.90	14.90	13.6
3	Insee2/L_{22}	17.40^{a-f}	12.27^{a-c}	19.20	16.30	2.90	4.38	0.93	15.10	15.1
4	Insee2/L_{27}	20.00^{a}	12.19^{a-d}	19.70	18.60	1.10	4.26	0.92	13.80	14.2
5	Insee2/L_{5}	16.73^{b-h}	11.94^{a-d}	17.90	15.20	2.70	4.38	0.91	14.40	14.4
6	Insee2/L_{26}	18.54^{a-d}	11.55^{a-e}	18.80	17.60	1.20	4.27	0.90	13.90	14.2
7	Insee2/L_{6}	17.07^{a-g}	11.32^{a-f}	18.90	17.30	1.60	4.32	0.93	15.40	14.8
8	Insee2/L_{4}	16.20^{b-i}	11.30^{a-f}	18.90	16.90	2.00	4.14	0.96	13.90	13.5
9	Insee2/L_{2}	18.54^{a-d}	11.28^{a-f}	19.60	17.70	1.90	4.33	0.90	14.10	13.8
10	Insee2/L_{13}	18.54^{a-d}	11.25^{b-f}	19.60	19.00	0.60	4.13	0.93	14.10	13.4
Check 1	$Agsh_2$201/$Agsh_2$309	16.38^{b-i}	10.96^{c-g}	19.20	16.90	2.30	4.22	1.06	14.90	12.9
Check 2	$Agsh_2$303/$Agsh_2$309	16.20^{b-l}	11.41^{a-f}	18.80	16.20	2.60	4.12	0.84	14.20	14.0
Check 3	$Agsh_2$201/$Agsh_2$318	12.21^{p-v}	8.38^{n-t}	18.70	17.00	1.70	4.23	0.78	13.10	14.1
Mean		14.26	9.11	18.60	16.60	2.00	4.10	0.87	14.20	14.2
%CV		12.61	9.23	5.19	7.66	42.60	4.32	7.94	4.57	4.10

higher yield but also had higher combining ability than inbred lines from the other two selection methods. Fasoula (1990) found that selection under high density environment tended to favour low yield and high competitive lines and selection under nil – competition favoured the high yield lines which could give the highest yield in pure stands (pure line or single cross) under high plant density. However, correlations between inbred lines and hybrid combinations were too low; 0.27 and 0.30 (Lonnquist and Lindsey, 1964), 0.09 and 0.11 (Gana and Hallauer, 1977), - 0.14, 0.07 and 0.22 (Lamkey and Hallauer, 1986) and 0.49 (Tokatlidis *et al.*, 1998) to be used as prediction criterion for the prediction of hybrid yield.

In another point of view, Lamkey and Hallauer (1986) found that selection among lines for yield per se could be used to separate a population into groups of high and low combining lines base on their performance per se. But performance per se within groups was not related to either specific combining ability or general combining ability. Therefore, after selection for performance per se the smaller group of selected lines could be crossed to a series of testers to identify the line with the greatest hybrid potential. Data in Table 4 supported the above suggestion. There were half and half of high (inbreds which yielded above 0.800 t/ha, L_{24}, 22, 27, 26 and 4) and low (inbreds which yielded below 0.800 t/ha, L20, 5, 6, 2 and 13) yielding lines in the top – 10 testcross hybrids, all of them were selected for performance per se (Table 1).

It should also be mentioned that six out of ten inbred lines in the top – 10 testcross (L_4, 5, 6, 22, 24 and 13) were derived from $Agsh_2$ – 303/309, two (L_2 and 20) from $Agsh_2$ – 201/309, and two (L_{26} and 27) from $Agsh_2$ – 201/318. Apparently, genetic sources played a significant role in hybrid combinations with the tester; different testers gave different results when crossed to the same group of inbred lines (Castellanos, *et al.*, 1998). Therefore, using a series of testers which would be used as counterparts of lines in hybrid combinations was suggested (Lamkey and Hallauer, 1986).

CONCLUSIONS

The results suggested that plant selection in the low competition environment was effective to discriminate between high and low yield inbred lines due to the clear expression of genotypes in the low interference between genetically different plants. There was no clear evidence for the advantage of selection under alternate environments between low – competition – high plant density. Variable results for the performance of intra – family hybrids from different sources of original germplasm suggested that the original hybrids possessed different predominant gene action. Original hybrid which had higher additive gene effect tended to give higher yield intra – family hybrids than the one that possessed higher non – additive gene effect. However, there was no clear cut advantage between low and high yields of selected lines when they were crossed to a single cross tester, even though the top – 4 testcross hybrids came from high yield lines. Moreover, there was no effect of selection methods in testcross hybrids with common tester. However, different germplasm responded differently to the common tester.

LITERATURE CITED

Castellanos, J.S., A.R. Hallauer and H.S. Cordova. 1998. Relative performance of testers to identify elite lines of corn (*Zea mays* L.). **Maydica** 43: 217 – 226.

Fasoula, D.A. 1990. Correlations between auto – and nil – competition and their implications in plant breeding. **Euphytica** 50: 57 – 60.

Fasoula, D.A. and V.A. Fasoula. 1997. Competitive ability and plant breeding. **Plant Breeding Review** 14: 89 – 138.

Fasoula, V.A. and D.A. Fasoula. 2002. Principle underlying genetic improvement for high and stable crop yield potential. **Field crop Research** 75: 191 – 209.

Gama, E.E.G.e. and A.R. Hallauer. 1977. Relation between inbred and hybrid traits in maize. **Crop Sci**. 17: 703 – 706.

Lamkey, K.R. and A.R. Hallauer. 1986. Performance of high x high, high x low, and low x low crosses of lines from the BSSS maize synthetic. **Crop Sci**. 26: 1114 – 1118.

Lonnquist, J.H. and M.F. Lindsey. 1964. Testcross versus S1 line performance in corn (*Zea mays* L.). **Crop Sci**. 4: 580 – 584.

Rasmusson, D.C. and R.L. Phillips. 1997. Review and interpretation: Plant breeding progress and genetic diversity from *de novo* variation and elevated epistasis. **Crop Sci**. 37: 303 – 310.

Tokatlidis, I.S., M. Doutsika – Sotiriou, A.C. Fasoulas and A.S. Tsaftaris. 1998. Improving maize hybrids for potential yield per plant. **Maydica** 43: 123 – 129.

Tokatlidis, I.S., M. Koutsika – Sotiriou and A.C. Fasolas. 2001. The development of density – independent hybrids in maize. **Maydica** 46: 21 – 25.

Troyer, A.F. 1999. Review and interpretation: Background of U.S. hybrid corn. **Crop Sci**. 39: 601 – 626.

Troyer, A.F. and R.W. Rosenbrook. 1983. Utilization of higher plant densities for corn performance testing. **Crop Sci.** 23: 868 – 876.