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# Heritability and heterosis of agronomical characteristics, yield and yield components of sweet and super sweet corn (*Zea mays* L.) genotypes

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**Key words:** Promising hybrids, Inbred lines, Kernel depth, Broad sense heritability.

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## Abstract

Sweet corn (Zea mays L.Saccharata) is one of the most popular vegetable in the world. This experiment was carried out in the agricultural and natural resources research center of Khorasan-Razavi, Mashhad, Iran during 2013-2014. A randomized complete block design with three replications was conducted in order to investigate the heritability of sweet and super sweet corn quantitative characteristics in 37 sweet corn inbred lines and hybrids. The genotypes were consisted of 13 inbred lines, 17 promising hybrids and 7 new commercial sweet and super sweet corn varietal. Plant height, ear length, ear diameter, kernel depth, row per ear, kernel per row and kernel yield was measured. Heterosis evaluated by combining parental data. Analysis of variance showed that there were significant differences between all studied genotypes except plant height, ear length, kernel depth, kernel number per eat, row per ear and kernel yield. Genetic diversity resulted in variation between hybrids and inbred lines.The highest and lowest conservable grain yield produced by Passion (12.5 ton/ha) and Harvest gold (0.32 ton/ha) respectively. Broad sense heritability ranged between 64% and 85%, for kernel depth and kernel yield, respectively. Results showed that hybrids which one of their parental line was Chase, Basin or temptation produced higher yield, kernel depth, kernel per row, row per ear and plant height than the other genotypes.

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**Introduction**

Sweet corn (Zea mays L.Saccharata) is one of the most popular vegetable in countries like United States of America and Canada. It is characterized by translucent, horny appearance of kernel when matures and wrinkled when it dries. The research reports indicate that the sweet corn has arisen as a mutant from field corn in the 19th century. Sweet corn is consumed in immature stage of the cob. Sweet corn derives from a mutation in genes that affect starch synthesis in the seed endosperm of dental corn which results in higher level of water soluble sugars and decrease starch (Dinges *et al*., 2001).

The efficiency of maize breeding programs would be significantly enhanced if superior crosses could be predicted before field evaluation based on screening of parental inbred lines. Even though remarkable advances in maize breeding have been achieved, field trials involve significant resources and are time consuming. However, field tests still have aunique role in modern hybrid breeding programs. Determining performances of inbred lines as potential hybrid parents in field experiments and diallel crosses are still widely used in sweet corn breeding programs (Kashiani *et al*, 2010., Assuncao *et al*, 2010).

Inbreeding the lines is the most frequent breeding technique in maize. Six to eight inbreeding results in sufficient homozygosity at heterozygote individuals. During this period, selection is performed base on important agronomical characteristics. The general and specific combining ability of lines is investigated too. The field test of hybrid's crossing continue for three to four generations (Hallauer, 1993., Hallauer and Miranda, 1988).

Sweet corn breeders have not relied on heterotic patterns in the development of commercial hybrids. Establishment and improvement of new heterotic patterns in sweet corn could be helpful for improving agronomic performance and adaptation of sweet corn in new regions of production. Furthermore, sweet corn breeders should theoretically be concerned with the risk of exhausting heterosis if the same inbred are recombined repeatedly without introduction of new heterotic combinations( Revilla *et al*., 2000).

Role of genetic regulation of yield component in order to enhance kernel yield has studied by several researchers (Hallauer and Eberhart,1966., Stuber *et al*., 1966).

Researchers reported that kernel yield, ear diameter, kernel number, ear number, days to anthesis and days to maturity affect by gene epistasis (Mihailov and Chernov, 2006).

(Melchinger *et al*., 1990) reported that corn kernel yield is highly controlled by additive × additive epistasis.

Sugar content and kernel nutritional content controlled by non-additive genes (Zhaoyuanzeng *et al*, 2002., Jyothi kumara *et al*, 2008). Other researchers reported that sugar and carbohydrate content affects by over dominant and specific combining ability (Asbishkhanduri *et al*, 2010., Zhaoyuanzeng *et al*, 2002., bordello *et al*, 2005).

Researchers investigated the effect of heterosis on yield and yield components of sweet corn genotypes via diallel analysis. They reported that genetic diversities results in significant difference between genotypes in respect of all studied traits except for ear industrial index and brix index. Measured characteristics enhanced in heterosis hybrids. Anthesis, plant height, ear height and kernel weight was controlled by dominant genes (Assuncao *et al*., 2010).

Significant heterosis reported for ear length, ear diameter, kernel weight and kernel number per row for maize (Devi and Sarma, 2005).

(Rokadia and Kaushik, 2005) found significant heterosis for leaves number per plant and grain yield at maize several crosses (L5×T1, L7×T1, L10×T1).

Introducing the proper sweet and super sweet corn single cross hybrids is the subject of this study. This study was performed in order to screening and introducing the best parental inbred lines and hybrids of sweet and super sweet corn in Iran.

## Materials and methods

*Plant materials*

This experiment was carried out in the Agricultural and Natural Resources Research Center of Khorasan-Razavi, Mashhad, Iran at during 2013 - 2014. A randomized complete block design with three replications was conducted in order to investigate the heritability of sweet and super sweet corn quantitative characteristics in 37 sweet corn inbred lines and hybrids. Genotypes were consisted of 13 inbred lines, 17 promising hybrids and 7 new released commercial sweet and super sweet corn cultivars (table 1). The studied hybrids derived from selfing of commercial hybrids and then crossing between inbred lines during 2012 and 2013. Parental lines of sweet corn (with Su locus) and super sweet corn (with Sh2 locus) crossed separately.

**Table 1.** The list of studied inbred lines, promising hybrids and commercial sweet and super sweet corn.

| | Single cross | | lines | | Commercial hybrids |
|---|---|---|---|---|---|
| 1 | Temptation-2 × Power house | 18 | K^ S13/2 -82 | 31 | Signet |
| 2 | Chase/s6 × Temptation/s6 | 19 | Merit | 32 | Shaker |
| 3 | Oppsision/s6 × K^ S2/2 -82 | 20 | E08716 | 33 | Passion |
| 4 | Challenger × Temptation | 21 | Shaker | 34 | Obsission |
| 5 | Challenger/s6 × Bassin/s6 | 22 | oppsision | 35 | Challenger |
| 6 | Basin × Oppsision | 23 | Signet | 36 | KSC 403 |
| 7 | Harvest gold × Merit | 24 | Passion | 37 | Merit |
| 8 | Chase/s2 × Temptation | 25 | Temptation | | |
| 9 | Challenger/s2 × Bassin/s2 | 26 | Bassin | | |
| 10 | Chase × Harvest gold | 27 | Power house | | |
| 11 | Opssision/s2 × K^ S2/2 -82 | 28 | Harvest gold | | |
| 12 | Power house × Temptation | 29 | K^ S2/2 -82 | | |
| 13 | Temptation × Temptation-2 | 30 | Chase | | |
| 14 | K^ S2/2 -82 × EO8716 | | | | |
| 15 | Temptation × Chase | | | | |
| 16 | Chase × Temptation-2 | | | | |
| 17 | Temptation × Power house | | | | |

In each plot, seeds planted in two 5m lenght rows with 75cm between two rows. The final plant population was 7.6 plant per square meter. Seeds planted in hills with 17.5 cm distance from each other by mid-June. The final experimental plot surface was 7.5 square meters for each treatment. Fertilizer application and hand weeding carried out according to practical instructions for the region.

*Evaluated characteristics*

*Morphological traits*

Plant height, ear height, tassel length, leaves number above ear, total leaves number and stem diameter was measured at 10 competitive plants in each plot.

*Kernel yield and yield components*

Plants and ears number in each plot counted before harvest. Total ears of each plot collected and weighted. Mean ear number per plant calculated. Kernel weight corrected base on 70% humidity. Yield components measured at 8 random ears in each plot. Yield components was include ear length, ear diameter, kernel depth, row per ear and kernel per row.

Heritability of morphological characteristics evaluated via expected value of traits. Heterosis evaluated by combining paternal data.( Hallauer and Miranda, 1988)

Analysis of variance performed by SAS ver 9.1. Means with significant differences compared with Duncan's multiple range test

## Results and discussions

*Statistical Genetical analysis*

Analysis of variance showed that there were significant differences between all studied genotypes in respect of plant height, ear length, kernel depth, kernel number per eat, row per ear and kernel yield (table 2). Genetic diversity resulted in variation between hybrids and inbred lines. Broad sense heritability ranged between 64 and 85%, for kernel depth and kernel yield respectively. The highest plant height (193cm) produced by Power house × Temptation. There was no significant difference between Chase × Harvest gold and Power house × Temptation in respect of plant height. The highest heterosis value (41.72%) observed for K^ S2/2 -82 × EO8716 in respect plant height. High heterisis value indicated high combining ability for plant height. The value of heritability was 82% for plant height. The results were in agreement with other researchers which reported significant heterosis for plant height (Assuncao *et al*, 2010; Alam *et al*, 2008 and Muraya *et al*, 2006).

**Table 2.** Analysis of variance of studied characteristics.

| | Traits | Number of kernels per row | Number of rows per ear | Grain depth(cm) | Plant height(cm) | Ear length(cm) | Grain yield |
|---|---|---|---|---|---|---|---|
| S.O.V | | | d.f. | | MS | | |
| Replication | 2 | 82.777** | 1.457* | 8.122** | 24.177* | 1.245** | 2.242** |
| Genotype | 37 | 137.421** | 8.803** | 8.976** | 1068.017** | 20.544** | 27.379** |
| Error | 74 | 13.718 | 1.156 | 1.396 | 71.873 | 2.983 | 1.465 |

ns, * and **: Not significant, significant at 5% and 1% levels of probability, respectively.

The highest ear length (22.2 cm) (21.8 cm) produced by Basin × Oppsision and Harvest gold ×Merit, while Temptation× Temptation-2 produced the lowest ear length (13.2 cm). The highest heterosis values for this trait were 51.17, 49.62 and 44.28%which observed for Harvest gold ×Merit, Chase/s2× Temptation, Basin × Obsession respectively. Heterosis was positive and significant for all crosses except for K^ S2/2 -82 × EO8716. Heterosis value for this cross was -12.16% which showed the depression of F1 generation compare with parental lines. Cross between K^ S2/2 -82 and EO8716 showed negative heterosis value for kernel yield, kernel depth, row number and kernel number. The same results reported by other researchers (Ojo *et al*, 2007; Nedev and Krapchev., 2006 and Revilla *et al*, 2006).

Kernel depth is avaluable commercial trait. It is important in canning and other food industries. Between inbred lines, the highest and lowest kernel depth belonged to Obsession(10.63 mm) and Temptation (5.57 mm) respectively. Between commercial hybrids the highest kernel depth (9 mm) belonged to Merit hybrid. There was no significant difference between Merit, Challenger, Passion and KSC 403 in respect of kernel depth. The lowest kernel depth (7.4 mm) belonged to Shaker. There was no significant difference between Obsession and Signet in respect of kernel depth.

Between crosses the highest kernel depth belonged to Harvest gold×Merit (9.95 mm) and Challenger/s6 × Basin (9.87 mm)(table 3).

**Table 3.** The mean and heterosis value for studied characteristics of sweet and super sweet corn genotypes.

| Genotype | Number of kernels per row | | Number of rows per ear | | Grain depth(mm) | | Plant height(cm) | | Grain yield | | Ear length(cm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | means | h | means | h | means | h | Means | h | Means | h | Means | h |
| Passion | 40.06$^{a-e}$ | - | 16.2$^{a-d}$ | - | 9.77$^{ab}$ | - | 164.13$^{d-k}$ | - | 7.94$^{c-g}$ | - | 19.73$^{a-e}$ | - |
| Signet | 19.6$^{jk}$ | | 11i | | 8.2$^{a-g}$ | | 139.86$^{l-O}$ | - | 2.77$^{m-r}$ | | 16.56$^{h-j}$ | - |
| Obbsision | 34.13$^{c-g}$ | - | 14.2$^{c-h}$ | - | 10.63$^{a}$ | - | 152.86$^{h-m}$ | - | 3.71$^{j-q}$ | - | 15.14$^{f-j}$ | - |

| Genotype | Number of kernels per row | | Number of rows per ear | | Grain depth(mm) | | Plant height(cm) | | Grain yield | | Ear length(cm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **means** | **h** | **means** | **h** | **means** | **h** | **Means** | **h** | **Means** | **h** | **Means** | **h** |
| Shaker | $36.33^{a-f}$ | - | $14.43^{c-h}$ | - | $8.21^{a-g}$ | - | $159^{e-l}$ | - | $9.70^{a-d}$ | - | $18.9^{a-g}$ | - |
| EO8716 | $38.6^{a-f}$ | - | $14.76^{c-g}$ | - | $8.58^{a-f}$ | - | $119.3^{o}$ | - | $6.43^{e-k}$ | - | $20.70^{a-c}$ | - |
| Merit | $32.13^{d-i}$ | - | $14.53^{c-h}$ | - | $7.4^{b-h}$ | - | $184^{a-d}$ | - | $8.63^{b-e}$ | - | $16.77^{c-i}$ | - |
| K^ S13/2 -82 | $33.53^{c-h}$ | - | $13^{f-i}$ | - | $8.10^{a-g}$ | - | $144.2^{j-m}$ | - | $7.56^{e-h}$ | - | $17.05^{c-i}$ | - |
| Chase | $29.73^{f-i}$ | - | $12.6^{g-i}$ | - | $7.32^{b-h}$ | - | $145.66^{i-n}$ | - | $0.80^{qr}$ | - | $15.46^{e-j}$ | - |
| K^ S2/2 -82 | $31.2^{d-i}$ | - | $13.06^{e-i}$ | - | $7.25^{b-h}$ | - | $131.66^{no}$ | - | $8.02^{e-f}$ | - | $16.71^{c-i}$ | - |
| Harvest gold | $23.8^{ij}$ | - | $14.86^{c-g}$ | - | $7.03^{b-i}$ | - | $143.46^{k-n}$ | - | $0.32^{r}$ | - | $12.07^{j}$ | - |
| Power house | $33.46^{c-h}$ | - | $15.06^{c-g}$ | - | $6.41^{d-i}$ | - | $153.66^{g-m}$ | - | $1.60^{p-r}$ | - | $18.7^{a-g}$ | - |
| Basin | $30.73^{e-i}$ | - | $12.86^{f-i}$ | - | $5.90^{e-i}$ | - | $153.93^{g-m}$ | - | $1.18^{qr}$ | - | $15.73^{d-j}$ | - |
| Temptation | $12.93^{k}$ | - | $10.5^{i}$ | - | $5.58^{f-i}$ | - | $136.66^{m-o}$ | - | $1.09^{qr}$ | - | $11.26^{j}$ | - |
| Temptation-2× Power house | $43.93^{ab}$ | - | $16.93^{ab}$ | - | $7.45^{b-h}$ | - | $183.13^{a-d}$ | - | $4.66^{h-p}$ | - | $20.6^{a-c}$ | - |
| Chase/s6× Temptation | 37.6a-f | - | $14.6^{c-h}$ | - | $8.92^{a-e}$ | - | $187.53^{a-c}$ | - | $1.78^{p-r}$ | - | $17.46^{b-i}$ | - |
| Oppsision/s6× K^ S2/2 -82 | 35.53a-g | - | $16.66^{a-c}$ | - | $9.54^{a-c}$ | - | $187.53^{a-c}$ | - | $5.20^{f-n}$ | - | $18.60^{a-g}$ | - |
| Challenger ×Temptation | $33.86^{c-g}$ | - | $13.2^{e-i}$ | - | $7.57^{a-h}$ | - | $164.33^{d-k}$ | - | $2.04^{o-r}$ | - | $15.86^{d-j}$ | - |
| Challenger/s6 ×basin | $37.6^{a-f}$ | | $12.86^{f-i}$ | - | $9.87^{ab}$ | - | $169^{b-h}$ | - | $6.96^{d-i}$ | - | $19.07^{a-g}$ | - |
| Basin×Oppsision | $44.93^{a}$ | $38.54^{**}$ | $15.33^{a-g}$ | $13.30^{**}$ | $7.25^{b-h}$ | $-12.28^{**}$ | $178^{a-f}$ | $16.03^{*}$ | $2.14^{n-r}$ | $-12.58^{**}$ | $22.2^{a}$ | $44.28^{**}$ |
| Harvest gold ×Merit | $41.93^{a-c}$ | $49.94^{**}$ | $18^{a}$ | $22.44^{**}$ | $9.95^{ab}$ | $37.90^{**}$ | $183.8^{a-d}$ | $12.25^{ns}$ | $2.77^{m-r}$ | $-43.85^{**}$ | $21.8^{ab}$ | $51.17^{**}$ |
| Chase/s2× Temptation | $41.93^{a-c}$ | $71.56^{**}$ | $14.4^{c-h}$ | $24.67^{**}$ | $6.54^{c-i}$ | $1.38^{ns}$ | $180.66^{a-e}$ | $27.98^{**}$ | $3.43^{k-r}$ | $261.58^{**}$ | $19.86^{a-e}$ | $49.62^{**}$ |
| Challenger/s2 × Bassin | $36.6^{a-f}$ | - | $11.934^{hi}$ | - | $9.17^{a-d}$ | | $166.8^{c-i}$ | | $6.69^{e-j}$ | | $20.13^{a-d}$ | - |
| Chase× Harvest gold | $40.8^{a-d}$ | $36.48^{**}$ | $16.46^{a-d}$ | $19.90^{**}$ | $8.29^{a-g}$ | $15.60^{**}$ | $190.2^{ab}$ | $31.56^{**}$ | $2.56^{n-r}$ | $351.83^{**}$ | $18.2^{a-g}$ | $32.18^{**}$ |
| Opssision/s2× K^ S2/2 -82 | $36.53^{a-f}$ | $8.77^{**}$ | $12.66^{g-i}$ | $22.24^{**}$ | $8.62^{a-f}$ | $6.70^{**}$ | $165^{d-j}$ | $31.81^{**}$ | $4.49^{h-p}$ | $-11.45^{**}$ | $14.73^{g-j}$ | $16.80^{**}$ |
| Power house × Temptation | $26.6^{g-j}$ | $54.02^{**}$ | $14.8^{c-g}$ | $15.77^{**}$ | $4.8^{hi}$ | $-19.98^{**}$ | $192.66^{a}$ | $32.72^{**}$ | $3.85^{j-q}$ | $185.65^{**}$ | $17.87^{a-h}$ | $19.28^{**}$ |
| Temptation× Temptation-2 | $35.73^{a-g}$ | - | $13.93^{d-h}$ | - | $5.48^{g-i}$ | - | $171^{a-h}$ | - | $2.98^{l-r}$ | - | $13.2^{ij}$ | - |
| K^ S2/2 -82 × EO8716 | $24.4^{h-j}$ | $-10.02^{**}$ | $12.66^{g-i}$ | $-8.98^{**}$ | $4.96^{i}$ | $-37.29^{**}$ | $177.86^{a-f}$ | $41.72^{**}$ | $4.88^{g-o}$ | $-32.44^{**}$ | $16.43^{c-i}$ | $-12.16^{**}$ |
| Temptation×Chase | $31.4^{d-i}$ | $68.75^{**}$ | $13.2^{e-i}$ | $14.28^{**}$ | $4.05^{i}$ | $-37.23^{**}$ | $175.6^{a-f}$ | $24.39^{**}$ | $5.20^{f-n}$ | $446.92^{**}$ | $18.53^{a-g}$ | $38.65^{**}$ |
| Chase× Temptation-2 | $36^{a-g}$ | - | $14.04^{d-h}$ | - | $3.96^{i}$ | | $175.46^{a-f}$ | | $4.27^{i-p}$ | | $16.55^{c-i}$ | |
| Temptation× Power house | $30.68^{e-i}$ | $61.49^{**}$ | $14.53^{c-h}$ | $13.68^{**}$ | $5.88^{e-i}$ | $-1.84^{*}$ | $185^{a-d}$ | $27.43^{**}$ | $4.66^{h-p}$ | $244.91^{**}$ | $18.8^{a-g}$ | $25.47^{**}$ |
| KSC 403/c | $37.46^{a-f}$ | - | $16.4^{a-d}$ | - | $8.8^{a-e}$ | - | $174.66^{a-g}$ | - | $10.55^{a-c}$ | - | $19.66^{a-e}$ | - |
| Merit/c | $42.33^{a-c}$ | - | $14.93^{c-g}$ | - | $8.98^{a-e}$ | - | $180.06^{a-e}$ | - | $5.81^{e-m}$ | - | $20.06^{a-d}$ | - |
| Challenger/c | $38.73^{a-f}$ | - | $14.4^{c-h}$ | - | $8.67^{a-f}$ | - | $154^{g-m}$ | - | $5.91^{e-l}$ | - | $19.33^{a-f}$ | - |
| Obsission/c | $39.93^{a-e}$ | - | $15.86^{a-e}$ | - | $8.42^{a-g}$ | - | $144.2^{j-n}$ | - | $6.32^{e-k}$ | - | $19.2^{a-g}$ | - |
| Passion/c | $34.66^{b-g}$ | - | $15.53^{a-f}$ | - | $8.58^{a-f}$ | - | $136.73^{m-o}$ | - | $12.05^{a}$ | - | $17.41^{b-i}$ | - |
| Shaker/c | $40.4^{a-e}$ | - | $14.06^{d-h}$ | - | $7.32^{b-h}$ | - | $171.66^{a-h}$ | - | $11.36^{ab}$ | - | $18.93^{a-g}$ | - |
| Signet/c | $37.46^{a-f}$ | - | $14.6^{c-h}$ | - | $9.86^{ab}$ | - | $158^{f-m}$ | - | $5.21^{f-n}$ | - | $18.4^{a-g}$ | - |
| LSD ($p<0.05$) | | 6.02 | | 1.7 | | 1.9 | | 13.7 | | 1.9 | | 2.81 |
| LSD ($p<0.01$) | | 7.9 | | 2.3 | | 2.5 | | 18.3 | | 2.6 | | 3.72 |

The highest heterosis value (37.90%) observed for Harvest gold × Merit. There was 2.74 mm difference between mean kernel depth of parental lines and F1 generation, which resulted in higher heterosis. The highest negative (-37.29,-37.23%) heterosis belonged to K^ S2/2-82 × EO8716 and Temptation × Chase, which showed low combining ability of crosses. Heterisis was significant in all crosses except for Chase/s2×Temptation, in respect of kernel depth(table 3). (Zare *et al.*, 2010) reported significant heterosis for kernel depth.

Kernel per row is an important component of maize yield. Comparison of means showed that the highest kernel per row produced by Basin × Oppsision (44.93 kernels), Temptation-2×Power house (43.93 kernels) and Harvest gold × Merit (41.93 kernels) (table 3).

The highest heterosis values detected for Chase/s2× Temptation (71.56%), Temptation × Chase (68.75%), Temptation × Power house (61.49%) and Harvest gold × Temptation (54.02%) in respect of kernel per row.

Among crosses, the highest row per ear (18 rows) belonged to Harvest gold×Merit. Between commercial hybrids the highest row per ear (16.4 rows) produced by KSC 403. The highest heterosis value (24.67%) observed for Chase/s2 ×Temptation(table 3). Positive heterosis in this characteristic reported by other researchers too (Muraya *et al*, 2006; Soengas *et al*, 2003).

The highest heterosis valuebelonged to Chase/s2×Temptation and Harvest gold×Merit in respect of kernel per row, row per ear and ear length(table 3).

Among crosses the highest and lowest kernel yield belonged to Challenger/s6×Basin (6.96 ton/ha) and Chase/s6×Temptation (1.78 ton/ha) respectively. Among inbred lines the highest kernel yield produced by Shaker (9.70 ton/ha). Between commercial hybrids the highest and lowest kernel yield produced by Passion (12.05 ton/ha) and Signet (5.21 ton/ha) respectively. There was 11.73 ton/ha difference between highest and lowest kernel yield(table 3).

The highest heterosis value belonged to Temptation × Chase (446.92%), Chase × Harvest gold (351.83%), Chase/s2×Temptation (261.58%) and Temptation × power house (245%) in respect of kernel yield. The same results reported by ( Revilla *et al*., 2000).

**Conclusion**

Results showed that hybrids which one of their parental line was Chase, Basin or temptation produced higher yield, kernel depth, kernel per row, row per ear and plant height. Such crosses showed high combining ability too. Using mentioned inbred lines will results in higher genetic efficiency In breeding programms.

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