HETEROSISFOR GRAIN YIELD AND QUALITY TRAITS IN THE HYBRIDS OF SWEET CORN (*ZEA MAYS* VAR. *SACCHARATA*) INBRED LINES

ELAYARAJA K, R.N. GADAG, JYOTI KUMARI, MARUTI R.T.,DHARAM PAUL

Abstract: Among the specialty corns, very limited attention is given to usages of sweet corn despite great potentiality in Indian market. Sweet corn is type of corn with a thin pericarp layer and it is consumed at immature grain stages of endosperm at 18 to 22 days after pollination. Higher sweetness is due to genetic mutations acting at different stages of starch biosynthesis pathway and can be used as a vegetable in many ways. The success of single cross hybrid technology in field corn, evident since last decade in India needs to be extended to sweet corn improvement to meet the requirements of various stakeholders and subsequent wider spread and usage. Hybrids were developed from eleven sweet corn inbred lines [IPSA-8751(P1), IPSA-8752(P2), IPSA-8753(P3), IPSA-8754(P4), IPSA-8755(P5), IPSA-8756(P6), IPSA-8757(P7), IPSA-8758(P8), IPSA-8759(P9), IPSA-8760(P10) and IPSA-8761(P11)] following half diallelmating design at Agricultural Research Station, ANGARU, Rajendranagar, Hyderabad during *rabi* 2008-09 . Altogether sixty seven entries including eleven inbreds and fifty five F_1s along with check (Priya), the most successful public sector commercial sweet corn cultivar, were evaluated in RBD at IARI Experimental Farm, New Delhi during *kharif* 2009. The biochemical analysis was done in the Biochemistry Lab of Directorate of Maize Research, New Delhi. The heterosis in hybrids (half diallel crosses) over standard check, Priya, was estimated for grain yield per plant and quality traits. There was significant amount of standard heterosis in the crosses viz., P1X P4,P2X P5, P4X P11 and P2X P7 for grain yield per plant. Similarly three eliitecrosses (P2X P7, P8X P11 and P4X P10) for sugar content, and for non reducing sugar content (P2X P7, P4X P10 and P3X P9) were identified, as both these traits are important sweet corn quality traits. So, the experimental hybrid involving P2X P7, expressed significant amount of standard heterosis for grain yield per plant, total sugar and non reducing sugar content. While this superior single cross hybrid for both productivity and quality need to be further evaluated in large scale multi-location testing for subsequent commercial release, other elite crosses can fit into appropriate strategy and planning towards further popularization of usage of corn at green ear stage.

Key words: Maize, sweet corn, Priya cultivar, diallele, standard heterosis.

Introduction: Sweet corn (*Zea mays* var. *saccharata*) is different from the other maize types by the presence of gene/genes which alter endosperm starch synthesis, resulting in kernels with enhanced sweetness which can be used as a vegetable in many ways. Genes like sugary (*su*), sugary enhancer (*se*) and shrunken (*sh2*) are involved and widely used individually or in combination in sweet corn breeding. The success of single cross hybrid development as a strategy of maize breeding has contributed to continuous increase in the productionand productivity, asevident since last decade in India. Hence, thistechnology needstobe extended to all specialty corns (baby corn, sweet corn, QPM, pop corn, higher vitamins and minerals etc.,) in general and to sweet corn improvement in particular. Though corn consumption at green ear stage is relatively familiar and one of the popular ways, sweet corns are especially suitable and amenable for this. It is pertinent to note that some efforts towards sweet corn improvement have been initiated in recent years using different approaches (Meena*et. al.*, 2005; Mohan and Gadag, 2005 and Gadag*et. al.*, 2006a and 2006b).

Sweet corn (*Zea mays* var. *saccahrata*), like field corn is also extensively grown in wide range of climatic conditions comprising of temperate, subtropical and tropical regions. The endosperm mutations specifically alter the starch synthesis pathway resulting in kernels with endosperm higher in sugar and phytoglycogen(in genotypes with *su*allele) and lower in starch (Tracy, 2001). However reduced starch content is one of the reasons for decrease in germination, seedling emergence, vigor, and uneven stands even in commercial sweet corn cultivars as compared tofield corn (Tracy, 2001). Conforming to the group and with general features of vegetables,fresh sweet corn is also perishable as a result of rapid decrease of sugar content, kernel desiccation, husk discoloration, and risk of pathogen infestation (Rodov*et al.,*2000). Availability of cultivar with high yield is one of the most important requirements for most sweet corn growers. As known, grain yield is a complex character that is determined by several components which have positive or negative effects. Further, it is important to examine the contribution of each of the various components in order to focus the attention to few with the greater influence on grain yield.

Due to the growing demand for sweet corn and to meet the requirements of various stake holders like producers, industry and consumers, studies are necessary for generating for more information about such usage at green ear stage. These would help to identify genes that are relevant for agronomic and industrial traits, as well as the consumer preferences. Since research related to improvement of yield and quality of sweet corn in India is limited, an important strategy can be use of heterosis from diverse breeding sources to make sweet corn hybrids. Technique that helps choose the best parents based on their performance, for selection of promising hybrids, is the diallel mating system (Ramalho*et al.*,1993). Diallel-mating design has been widely used to provide information on the performance of parental populations and their heterotic pattern in crosses, identify heterotic groups and predict performance of new populations (composites) derived from such crosses(Miranda, 1985). Thus,the present investigation is devised especially to investigate standard heterosis of experimental crosses for the purpose of identification of superior crosses for grain yield and quality traits of sweet corn.

Methodology: The genetic materials used in the present study were eleven sweet corn inbred lines [IPSA-8751(P1), IPSA-8752(P2), IPSA-8753(P3), IPSA-8754(P4), IPSA-8755(P5), IPSA-8756(P6), IPSA-8757(P7), IPSA-8758(P8), IPSA-8759(P9), IPSA-8760(P10) and IPSA-8761(P11)] were crossed in half diallel design at Agricultural Research Station, ANGARU, Rajendranagar, Hyderabad during *rabi* 2008-09 generating a total fifty five F_1s. Altogether sixty seven entries including eleven inbreds and fifty five F_1s along with check (Priya), the most successful public sector commercial sweet corn cultivar, were evaluated in RBD at IARI Experimental Farm, New Delhi during *kharif*2009. Each experimental plot consisted of two rows, each of 5m length with 75 cm inter row and 20 cm plant-to-plant spacing.Standard agronomic practices were followed for raising and maintenance of the crop.

The observations recorded on grain yield per plant wererecorded after harvest at dry maturity stage as the average of five ears randomly selected from each plot. These parameters give an idea regarding grain characteristics and productivity of genotypes with bearing and implication on economics of seed production which is an important consideration at the final product development stage.Kernel quality traits, *viz.*, totalsugars, reducing and non-reducing sugars were recorded from dry mature grain. It is evident that there is good correlation between the quality parameters measured at both green ear and dry grain stage of sweet corn. The biochemical observations like reducing sugar, non-reducing sugar, total sugar content were taken in the Biochemistry Lab of Directorate of Maize Research, New Delhi. The total sugar content was recorded with the help of near infra red spectroscopy. Reducing sugar was analyzed by Nelson Somogeyi method (Nelson, 1944),non-reducing sugar was obtained through subtracting the reducing sugar from the total sugar.

Heterosis is an increase or decrease in the performance of F_1 over standard variety (Priya) was calculated by the formula

$$\text{Standard or Economicheterosis (\%)} = \frac{\overline{\text{F}}_1 - \overline{EP}}{\overline{\text{EP}}} \times 100$$

Where, $\overline{F_1}$ = Mean value of F_1

EP = Mean value of Economic or Standard Parent

The test of significance was made of Het_1, values and indicated on the percentage values of heterosis. The value of CD was used for testing the significance of heterosis.

$$Het_1 = \overline{F_1} - \overline{EP}$$

Results and discussion: The term heterosis refers to the phenomenon in which the F_1 population obtained by crossing of two genetically dissimilar gametes or individuals show increased or decreased vigour over the better parent or over the mid-parental value. Mather and Jinks (1971) defined heterosis as the amount by which the F_1 hybrid mean exceeds its superior parent. In plant breeding programmes, conventionally, heterosis is referred to denote the expression of increased vigour of the hybrid over the better parent. But, since heterosis is also expressed over mid-parental value, it needs some distinction. The word heterobeltiosis has been proposed to describe the improvement of the heterozygote in relation to better parent of the cross and now this term is precisely being used to connote the expression of heterosis over the better parent. Further, it is realized that the heterosis is of no practical value unless the performance of the hybrids exceeds the well adapted variety of the particular region. This kind of heterosis expressed over the commercial cultivar has come to be designated as the economic or standard heterosis. Several workers, namely, Jinks (1954, 1955), Kempthorne(1956) and Jinks and Jones (1958) demonstrated a correlation between heterosis and epistasis.

Standard heterosis was recorded on the basis of the performance of 'Priya', the best check for all the traits analyzed. Regarding the direction of heterosis, in general positive values are desirable for these traits. The hybrids identified in the experiment are superior over this standard check for many traits. In the present study,only four crosses was manifested significant heterosis in positive direction for grain yield with range of -27.7% (P1X P5) to 13.47% (P1X P4).The cross P1X P4 expressed highest heterosis with 13.47 % followed by P2X P5 (10.69%),P4X P11 (10.33%)andP2X P7(10.22%) respectively for grain yield per plant (Table-I).Kumar and Satyanarayana (2006) observed that DMV-11 x CM-120 recorded the highest standard heterosis for grain yield per plot in addition to positive significant heterosis for yield component traits indicating its potential in heterosis breeding programmes. Similar findings reported in QPM crosses by Hossain*et al.* (2007).For sugar content,among the fifty five crosses, standard heterosis was observed from -31.21% (P1X P10) to 13.24% (P2X P7) with only three crosses like P2X P7, P4X P10 and P8X P11 showed significant standard heterosis for this trait.The present study revealed that P2X P7 as the best cross with highest heterosisfor sugar content with 13.24%heterosis , followed by P8X P11 (12.49%) and P4X P1 (10.32 %).

The present investigation identifiedsix crosses with significant standard heterosis in positive direction which is desirable direction of heterosis for non-reducing sugar. The hybrid with highest heterosis for non-reducing sugar was P2X P7 (17.65%), followed by P8X P11 (14.55%), P8X P10 (12.05%), P4X P10 (11.99 %), P3X P9(10.27%) and P2X P6(10.11%) and rangefor this trait was varied from -34.02% (P1X P10) to 17.65% (P2X P7). Sinha*et al.* (2004) analysed and found that high significant positive economic heterosis for quality traitsover the best control and suggested over-dominance effect as these hybrids also exhibited significant positive heterobeltiosis. By evaluating experimental sweet corn hybrids in two loctions,Khanduri*et al.*(2010) identified an elite hybrid exhibiting significant heterosis over all the three composites (Priya, win Orange and Madhuri). Knowledge of germplasm diversity and of relationships among breeding material has significant impact on improvement of crop plants and is useful in planning crosses for hybrid and line development and assigning lines to heterosis groups (Hallauer*et al*., 1988). Reis *et al.* (2011) indicated desirability of hybrid development in sweet corn even from the point of better germination and high vigour in addition to emphasis and adaptability of genotypes to specific regions/conditions.

Among the crosses,manifestation of significant amount of heterosisfor yield and both the quality traits are P2X P7 (for grain yield per plant, total sugar and non reducing sugar content). The experimental crosses P8X P11 and P4X P10 exhibited high heterotic performance for both total sugar content and non reducing sugar content. Both these traits are important sweet corn quality traits which would be useful for transferring sweet corn quality traits into normal corn inbreds to increasesweetness in normal corn(Kumari*et al.,* 2008). The crosses P1X P4,P2X P5 andP4X P11 showed highest heterosis for grain yield per plant only. In sweet corn cultivars, loss of moisture and consequent shriveldedness led to less grain yield per plant. But these crosses showed highest heterosis level for grain yield only. Simultaneous improvement of other quality traits through marker assisted selection in the otherwise high productivity genotypes can lead to highly desirable genotypes, which have huge potential for commercial release.So, this study has led to identification of best cross P2X P7, which expressed significant amount of standard heterosis for grain yield per plant, total sugar and non reducing sugar content. This superior single cross hybrid need to be further evaluated in large scale multi-location testing for subsequent commercial release in the form of superior sweet corn meeting both the requirements of yieldand standard quality parameters.

In addition, some of the elite crosses for specific desirable traits can further be used in specific strategies. For example, three crosses (P1XP4,P2XP5, and P4XP11) were especially desirable from the higher productivity point of view. These hybrids, with reasonably good quality traits in terms of sweetness (compared to the field corns) can find their way as alternative to the latter. As mentioned above, if field corns are also currently used in green ear stage consumption, any improvement in the sweetness would be desirable and preferable. Similarly, the hybrid P4XP10 found to be excellent in terms of both total sugar and non-reducing sugar content. This may find its way as a high quality sweet corn, despite its modest productivity. The other two crosses viz., P8XP11 and P3XP9, possess higher sugar content and non-reducmg sugar,respectively and need specific attention from quality and taste preferences. Thus,the nascent and less familiar utility of sweet corn in Indian context can be used as an opportunity to fill the gap and meet the requirement of new sweetcorn cultivars at different stages and levels of productivity and quality.Puddhanon*et al.*(2010) have reported the effectiveness of systematic approach in sweet corn improvement, resulting in elite hybrids considering both productivity and quality components. These examples emphasize on the prospects and potentiality of utilization of hybrid technology in sweet corn. These are the conformity with the results of present investigation, in which elite hybrids meeting most of the requirements for commercialization are identified.

Conclusions and implications: The study revealed the experimental hybrids developed will apart from broadening the genetic base of available sweet corn germplasm, identified elite hybrids which are ready to be used in multi-location trials. Hybrid breeding emphasizing in single cross hybrids as direct option startedrelatively late(after 1990s) in commercial way in field corn,in India.In this context, this study would strengthen the national maize program for specialty corn in general and, for sweet corn in particular.This heterosis study has identified the crosses like P2X P7 is superior for grain yield per plant, total sugar content and non reducing sugar content.These hybrids can now go into large scale multilocation testing for facilitating their possible identification and reflecting significant release. Besides, this study has led to the identification of some of the best hybrids like P8X P11,P3XP9 and P4X P10, (for quality); P1X P4 P2XP5 and andP4XP11 (for higher productivity). These hybrids have high potential for commercial exploitation of heterosisin sweet cornfor specific productivity and/or quality traits, reflecting the outcome of the present study with practical importance.

References:

1. Gadag R.N., Singh, R.D. and Singh, R.D. (2006). Development of maize cultivars to be used as vegetables. Souvenir of National convention on 'Knowledge – driven agricultural development: Management of change'. Organized by ARS forum, March 24-26, New Delhi S-IV, 9, pp 73-74.
2. Gadag, R.N.,Meena, C.R., Jyoti Kumar, R.D. Singh and Singh, B.B. (2006).Utility of filed corns for improvement of sweet corns-Analysis and Approaches. Souvenir of National convention on 'Knowledge – driven agricultural development: Management of change'. Organized by ARS forum, March 24-26, New Delhi S-I, 12, Pp41- 42.
3. Hallauer, A.R., Russel, W.A. and Lamkey, K.R. (1988).Corn breeding.*In*: Corn and Corn Improvement, (eds. Sprague, G.F. and Dudley, J.W.), *Agronomy Monogr.*,18, ASA, CSSA and SSA, Madison, WI, pp. 463-564.
4. Jinks, J.L. (1954). The analysis of continuous variation in a diallel cross of *Nicotianarustica* varieties. *Genetics***39**: 767-778.
5. Jinks, J.L. (1955). A survey of the genetical basis of heterosis in a variety of diallel crosses. *Heredity***9**: 223-238.
6. Jinks, J.L. and Jones, R.M. (1958).Estimation of components of heterosis.*Genetics*,**43**: 223-234
7. Kempthorne, O. (1956). The theory of diallel crosses. *Genetics***41**: 451-459.
8. Khanduri, A., Prasanna, B.M., Hossain, F. and Lakhera, P.C. (2010).Genetic analyses and association studies of yield components and kernel sugar concentration in sweet corn.*Indian Journal of Genetics and Plant Breeding* **70**(3): 257-263.
9. Kumar,P.P. and Satyanarayana,E. (2006).Heterosis for yield and yield components in full season maize genotypes.*Indian J. DrylandAgr. Res. Develop.***21**(1): 88-90.
10. Kumari,J., Gadag,R.N. and Jha,G.K. (2008).Combining ability and heterosis in field vs sweet corn (*Zeamays*) hybrids using line by tester mating design.*Indian J. Agr*. Sci. **78**(3): 261-264.
11. Mather, K. and Jinks, J.L. (1971).Biometrical genetics 2nd edition. Chapman and Hall, London, 249-71.
12. Meena, C.R., Singh, R.D., Singh, B.B. and Gadag, R.N. (2005).Evaluation of crosses between field and sweet corns for productivity and kernel biochemical composition. Maize Gen. Coop. Newsletter: 79/26.
13. Miranda, F., J.B. (1985).Breeding methodologies for tropical maize. In: BRANDOLINI, A.; SALAMINI, F. (Ed.) Breeding strategies for maize production improvement in the tropics. Firenze: FAO;InstitutoAgronomico per l'Oltremare.
14. Mohan, M.andGadag, R. (2005).Characterization and genetic análisis of sweetcornlinesadaptedtoIndianconditions**.** (Abstract), 9th ARMW, Beijing, P. 11-12.
15. Nelson, N. (1944). A. photometric adoption of the Somogyi's method for determination of glucose.*J. Biol. Chem.*,**153**: 375-378.
16. Puddhanon, Un-srisong, P., Deesripan, S., Siripin, S., Jan-orn, S. and Songjunthuek, S.J. (2010).Good quality bicolor sweet corn hybrid "Wan Maejo 84". [Thai].*Journal of Agricultural Research and Extension***27**(3): 11-18.
17. Ramalho, M.A.P., Santos, J.B. and Zimmermann, M.J. (1993).Genéticaquantitativaemplantasautógamas.Editora UFG, Goiânia, 271p.
18. Reis, Pereira, L.S.D., Silva, M.G.R. and Meireles, F.D. (2011). Effect of Heterosis on sweet corn seeds quality. *RevistaBrasileira de Sementes***33**(2): 310-315.
19. Rodova, V., AzicaCopela, NehemiaAharonia, YairAharonia, AharonWiseblumb, BatiaHoreva and YacovVinokura (2000). Nested modified-atmosphere packages maintain quality of trimmed sweet corn during cold storage and the shelf life period. *Postharvest Biology and Technology***3**(18): 259-266.
20. Sinha,S.S.,Dubey,R.B.,LakshyadeepandPunia,S.S. (2004).Heterosis for quality traits in single cross hybrids of maize (*Zea mays* L.).*Indian Journal of Agricultural Biochemistry* **17**(1): 37-39.

21. Tracy, W.F. (2001). Sweet corn, In: A.R.Hallauer (ed). Speciality corns. 2nd ed. CRC Press, Boca Raton, F L. p 155-198.

Table I. Estimates of percent heterosis for grain yield and quality traits of sweet corn

Crosses	Grain yield per plant	Total sugar	Non reducing Sugar
P1XP2	6.35	-14.33**	-13.52**
P1XP3	-6.90	-8.85	-5.88
P1XP4	**13.47****	0.14	1.72
P1XP5	-27.70**	-15.53**	-15.43**
P1XP6	8.20	-10.08*	-9.45
P1XP7	9.85	-15.30**	-14.40**
P1XP8	2.97	-15.20**	-17.03**
P1XP9	-15.82**	-13.50**	-12.77*
P1XP10	-3.42	-31.21**	-34.02**
P1XP11	6.66	-6.37	-5.23
P2XP3	-1.91	-3.40	-2.32
P2XP4	5.08	-20.66**	-20.09**
P2XP5	**10.69***	-12.75*	-11.55*
P2XP6	8.42	8.57	**10.11***
P2XP7	**10.22***	**13.24***	**17.65****
P2XP8	-11.72*	0.07	1.72
P2XP9	6.33	-16.05**	-14.62**
P2XP10	-11.76*	-5.76	-4.41
P2XP11	-0.65	-18.86**	-18.44**
P3XP4	4.28	-18.34**	-18.18**
P3XP5	-0.35	-11.24*	-10.99*
P3XP6	4.67	-11.85*	-11.77*
P3XP7	-0.28	0.33	2.10
P3XP8	1.42	-7.91	-6.07
P3XP9	5.30	7.29	**10.27***
P3XP10	9.85	-2.34	-2.13
P3XP11	8.47	5.43	7.26
P4XP5	1.04	3.40	3.85
P4XP6	3.19	-4.01	-1.78
P4XP7	1.84	5.97	6.42
P4XP8	-1.82	-4.51	-2.66
P4XP9	6.72	-0.38	0.91
P4XP10	-0.25	**10.32***	**11.99***
P4XP11	**10.33***	0.85	-0.94
P5XP6	4.48	-6.07	-5.04
P5XP7	-3.55	-11.14*	-7.67
P5XP8	4.85	-0.26	-4.82
P5XP9	8.22	-5.95	-6.76
P5XP10	5.11	-10.95*	-10.14*
P5XP11	-10.20*	-10.32*	-9.73*
P6XP7	-6.98	-8.99	-4.69
P6XP8	-14.98**	-1.56	-0.50
P6XP9	-7.32	-19.36**	-16.96**
P6XP10	7.07	3.56	4.66
P6XP11	-1.19	2.83	5.70
P7XP8	0.13	5.57	6.67
P7XP9	-1.99	2.93	4.04
P7XP10	-10.71*	-10.86*	-9.45
P7XP11	5.30	-2.29	2.66
P8XP9	-10.43*	3.78	5.54
P8XP10	-11.59*	8.85	**12.05***
P8XP11	-10.36*	**12.49***	**14.55****
P9XP10	-18.95**	4.93	6.32
P9XP11	-5.20	-7.44	-7.14
P10XP11	6.94	3.54	4.48
SE	3.02	0.72	0.52

P1: IPSA-8751, P2: IPSA-8752, P3: IPSA-8753, P4: IPSA-8754, P5: IPSA-8755, P6: IPSA-8756, P7: IPSA-8757, P8: IPSA-8758, P9: IPSA-8759, P10: IPSA-8760 and P11: IPSA-8761

* and** indicate significance level at 5% and 1% respectively

***

Directorate of Seed Research, Mau, Uttar Pradesh 275 101
Division of Genetics, IARI, New Delhi 110 012
NBPGR, Pusa Campus, New Delhi 110 012
Central Research Institute for Jute and Allied Fibres, Barrackpore, Kolkatta 700 120
Directorate of Maize Research, Pusa Campus, New Delhi 110 012