Mysore J. Agric. Sci., 52 (3) : 560-565 (2018)

Testing Early Generation (F_4) Maize (*Zea mays* L.) Inbred Lines for General Combining Ability

H. H. Sowmya and E. Gangappa
Department of Genetics and Plant Breeding, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
E-mail: sowmyahh.cta@gmail.com

Abstract

Testing of early generation (F_4) inbred lines for general combining ability (*gca*) enables plant breeders to discard undesirable ones and identify those that are desirable for the production of superior hybrids. In this context, 15 F_4 inbred maize lines selected based on narrow anthesis-silking interval (ASI) and high grain yield potential were evaluated for their *gca* using testcrosses for ASI, cob weight plant^{-1} and grain yield plant^{-1}. The analysis of variance for combining ability revealed significant differences among the test crosses for all the three traits. The F_4 inbred lines varied widely for their *gca* and suggested good ability of testers to discriminate the inbred lines for *gca*. Five of the 15 F_4 inbred lines were identified as good general combiners for cob weight^{-1} and grain yield^{-1}. Non-significant correlation between per se performance and *gca* effects suggested that per se performance of inbred lines is not a good indicator of their *gca* effects for any of the three traits. However, significant positive and fairly high magnitude of correlation between per se performance of hybrids and sum of parental *gca* effects indicated good predictability of hybrids per se performance based on their parental *gca* effects for all the three traits investigated. Further, significant positive and high magnitude of correlation between parental difference and mid-parent heterosis suggested the need for using diverse parents for maximizing the probability of realizing heterotic hybrids for grain yield of maize.

Keywords: Anthesis-silking interval, Early generation testing, General combining ability

Single cross hybrids are the only cultivar types used for commercial production of maize in most parts of the world. Hybrids have played a vital role in increasing the area and productivity of maize. Superior hybrids are produced if the parents involved have good general combining ability (*gca*) which is the relative ability of a genotype to transmit its desirable genes to a hybrid. The concept of *gca* (Sprague and Tatum, 1942) is a widely accepted criteria for assessing the inbreds for use them as parents in the development of heterotic hybrids.

Testing of inbred lines for their *gca* during early (F_4) stages of their development help save substantial resources in terms of time, labour and land resources (Bernardo, 2010; Fasahat *et al.,* 2016). Early generation testing enables plant breeders to discard most of the undesirable inbreds and allows greater expenditure of resources on most promising ones and identifies those that are desirable for the production of superior hybrids (Bernardo, 2010; Ali *et al.,* 2011; Ai-Zhi and Zheng, 2012). Line × Tester analysis (Kempthorne, 1957) is one of the simplest, efficient and most widely used methods of evaluating a large number of inbred lines/parents for their *gca* (Fasahat *et al.,* 2016). Apart from providing an objective criterion for choosing parents, combining ability (CA) also provides useful clues about mode of action of genes controlling economically important traits. Another utility of CA of the parents is their predictive power of hybrid *per se* performance in the absence of significant hybrid *sca* effects. In the background, an investigation was undertaken to assess the *gca* of F_4 inbred lines developed from a cross between parents differing for anthesis-silking interval (ASI) and grain yield potential.

Material and Methods

Basic material: Fifteen $F_{3,4}$ inbred lines were selected based on narrow ASI (0 days) and high grain yield

(20 g plant^{-1}) and four proven testers (MAI-264, MAI-105, MAI-137 and MAI-215) constituted the basic genetic material. These 15 inbred lines were derived from the cross between MAI-349 and BGD-89 which are contrasting for ASI and grain yield potential.

Development of experimental material: The 15 F_4 inbreds were crossed with the four testers following line × tester mating design (Kempthorne, 1957) to develop 60 single cross hybrids (SCH) during summer 2017 at the experimental plots of the Department of Genetics and Plant Breeding (GPB), University of Agricultural Sciences (UAS), Gandhi Krishi Vignana Kendra (GKVK), Bengaluru. The resultant 60 SCH, their parents and four checks *viz*., NAH 2049, NAH 1137, MAH 14-5 and Bio 9544 constituted the experimental material.

Field evaluation of experimental material: The SCH and four checks were evaluated twice at the experimental plots of department of GPB, UAS, GKVK, Bengaluru during 2017 rainy season and 2017 post-rainy season following simple lattice. The parents were also evaluated twice in two-replicated randomized block design. Each entry was sown in two-rows of 3m length with a spacing of 0.6 m × 0.3 m. Recommended package of practices were followed to raise a healthy crop.

Sampling of plants and data collection: Data was recorded on ten randomly selected plants in each hybrid, parents and checks for ASI, cob weight plant^{-1} and grain yield plant^{-1}.

Statistical analysis: The replicated mean data of hybrids, parents and checks pooled over the two seasons was used for statistical analysis. Data of F_1 hybrids were subjected to combining ability analysis following line × tester linear model (Kempthorne, 1957). The *gca* effects of 15 lines were estimated and their statistical significance was examined using't' test. The significance of mean squares attributable to testers and lines × testers' interaction provided the diagnosis of additive genetic variance (ó^2_A) and dominance genetic variance (ó^2_D). The ó^2_A and ó^2_D were estimated using co-variances of half sibs and full sibs (Kempthorne, 1957).

General combining ability of inbred lines: The practical phase of hybrid maize breeding is identification of elite inbred lines with high *gca* for use as parents for developing hybrids that are superior to existing ones (El-Hosary, 2014). Identification of such elite inbred lines during early generation is the major strategy adopted by most commercial plant breeders to maximize genetic gain per unit time and resources. Early generation testing involves the evaluation of test crosses at an early selfing generations such as F_3 or F_4. It assumed that, the test crosses performance of F_3 or F_4 inbred lines does not change substantially with continued inbreeding (Bernardo, 2010). This assumption is based on the reports that *gca* is controlled by additive effect genes which control the inheritance of phenotypes that are fixable (Ai-Zhi and Zheng, 2012).

Components of genotypic variance: Combining ability (CA) approach was used for dissecting and estimating the components of genotypic variability. The advantage of CA analysis is that, besides providing the estimates of *gca* effects of parents, the analysis provides the most efficient method for diagnosis and estimation of ó^2_A and ó^2_D (Kempthorne, 1957). Statistical robustness and genetic neutrality of CA approach provides dependable estimates of ó^2_A and ó^2_D for designing suitable breeding and selection strategy for maize genetic improvement programme (Bernardo, 2010).

Relationship of gca *effects of inbred lines with their per se performance:* Relationship between *per se* performance of 15 F_4 inbred lines and their *gca* effects were determined by estimating Spearman's Rank Correlation Coefficient for three quantitative traits (QTs). High magnitude of positive significant and non-significant correlation indicates good and poor predictive power of *per se* performance, respectively.

Relationship of hybrid per se performance with sum of parental gca *effects:* Pearson's Correlation Coefficients between hybrids *per se* performance and sum of *gca* effects of their parents were estimated for three QTs (Schrag *et al.,* 2009). Significant correlation with fairly high coefficient of correlation and determination was interpreted as high predictability of hybrid per se performance based on their sum of parental *gca* effects.

Relationship of parental per se performance difference with hybrid heterosis: Correlation between the parental three QTs *per se* difference and hybrids' mid parent heterosis (MPH) was estimated (Turner, 1953) to explore the possibility of predicting hybrids' MPH based on their parental per se performance differences for the three QT's.

Results and Discussion

Analysis of variance (ANOVA): ANOVA indicated significant differences among the test crosses for all the three QTs (Table 1). Significant mean squares due to lines, testers and interaction of lines and testers suggested substantial variability for *gca* effects of lines and testers and *sca* effects of their crosses for all the three QTs except ASI for which testers did not differ significantly. Significant variances among the crosses could be attributed to greater diversity between lines and testers for the three QTs. The mean squares attributable to lines were of a larger magnitude than those of testers and line × tester for all the three QTs indicating greater contribution of the lines than the testers towards total variation among the hybrids. The similar results were reported by Kanagarasu *et al.* (2010).

General combining ability of inbred lines: In the present study, the inbred lines differed widely for their *gca* effects for all the three QTs. The wide range in estimates of *gca* effects of the 15 F_4 inbred lines suggested good ability of the testers to discriminate the lines for their *gca* effects for cob weight plant^{-1} and grain yield plant^{-1}, but not for ASI. The differences in *gca* effects of the lines are attributable to differences in frequencies of genes that are transmitted to the progeny with the additive effects (Falconer and Mackay, 1996). The differences in *gca* effects of lines could also be attributable to possible role of different alleles controlling *gca* effects of different inbred lines (Ai-Zhi and Zheng, 2012). The differences in gene frequencies among the lines suggest their significant genotypic differences, thus justifying their selection for the present study.

As expected, different inbred lines were desirable general combiners in both direction (Table 2) and

TABLE 1

Analysis of variance of combining ability for quantitative traits

Source of variation	Degrees of freedom	ASI (days)	Cob weight plant^{-1} (g)	Grain yield plant^{-1} (g)
Crosses	59	02.06**	1928.01**	1299.24**
Lines	14	02.43**	4191.57**	3997.71**
Testers	03	00.57	1719.74**	1357.24**
Line×Tester	42	01.82**	1027.96**	1082.43**
Error	156	00.81	0059.68	0099.05

*Significant at P=0.05; ** Significant at P=0.01

TABLE 2

Estimates of *gca* effects of F_4 inbred lines for quantitative traits

Codes of F_4 Lines	ASI (days)	Cob weight plant^{-1} (g)	Grain yield plant^{-1} (g)
139	0.18	-17.18 **	-09.26 **
163	-0.01	-14.17 *	11.30 **
188	0.05	-04.52 *	-05.10
205	-0.26	-05.10 *	-05.60 *
213	-0.69 **	06.89 **	11.81 **
221	0.30	20.06 **	17.74 **
238	-0.76 **	11.87 **	05.49
265	0.74 **	15.04 **	05.41
33	0.12	-02.08	-03.52
42	0.12	11.06 **	08.62 **
51	-0.07	08.50 **	06.86 *
65	0.74**	-03.44	-04.42
81	-0.26	-10.07 **	-03.04
82	0.05	-20.57 **	-09.28 **
90	-0.26	03.70	-04.40
SEm±	0.26	02.18	02.82
CD (gi – gj) @ P=0.05	0.51	4.32	05.58

*Significant at P=0.05; ** Significant at P=0.01

magnitude for different traits. Thus, no single line was a desirable combiner for all the three QTs. For instance, lines such as 163, 238 and 65 were desirable general combiners for only grain yield plant^{-1}, cob weight plant^{-1} and ASI, respectively (Table 2). However, inbred line, 265 was a good general combiner for two traits, namely, cob weight plant^{-1} and ASI; while, the inbred lines 213, 221, 51and 42 were desirable general combiners for grain yield plant^{-1} and cob weight plant^{-1}. The inbred lines 42, 51, 213, 221 and 265 need greater attention and need to be evaluated on a large scale to confirm their superiority for *gca* effects. Identification of most desirable inbred lines during early generation of their development help maximize genetic gain per unit time and resources (Bernarando, 2010; Ai-Zhi *et al*., 2012). The results are in conformity with those of Manpreet *et al.* (2007). It should however be noted that the estimates of *gca* effects of 15 inbred lines are relative to and are dependent on particular set of parents included in the experiment. The similar results were reported by Fasahat *et al.* (2016).

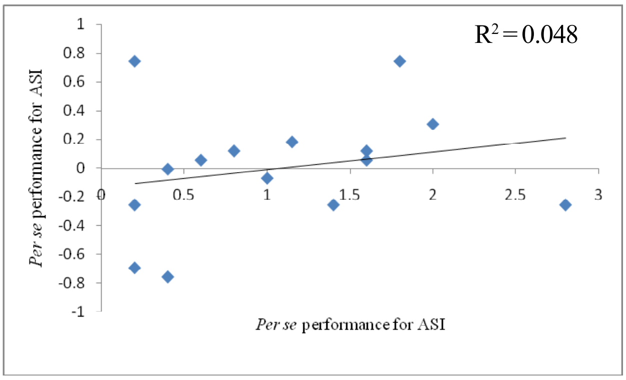

Fig. 1: Correlation of per se performance of F_4 inbred lines with gca *effects for ASI*

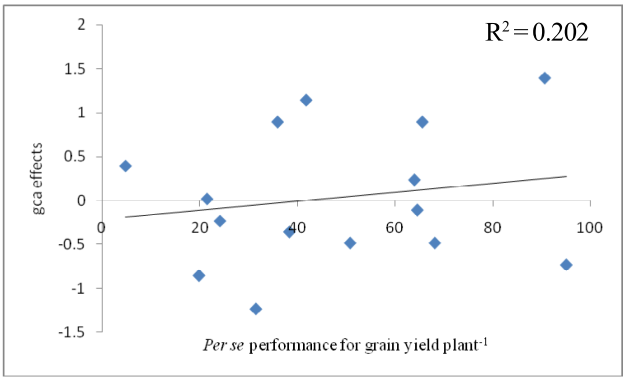

Fig. 2: Correlation of per se performance of F_4 inbred lines with gca *effects for cob weight plant^{-1}*

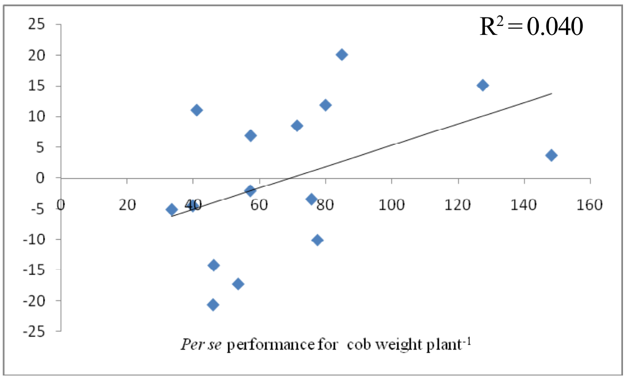

Fig. 3: Correlation of per se performance of F_4 inbred lines with gca *effects for grain yield plant^{-1}*

Relationship of gca *effects of inbred lines with their per se performance:* Significant positive but low magnitude of correlation between per se performance of the lines and their *gca* effects for ASI, cob weight plant^{-1} and grain yield plant^{-1} (Fig. 1, 2, 3), suggested that *per se* performance of the lines is not a good indicator of their *gca* effects for any of the traits. The poor correlation between per se performance and *gca* effects of inbred line could be attributable to different sets of genes controlling per se performance and *gca* effects for target traits. The results are in conformity with those of Ai-Zhi and Zhang (2012).

Components of genotypic variance: In the present study, the significance of mean squares attributable to lines/testers and lines × tester's interaction (Table 1) provide evidence for the involvement of both ó$^{2}_{A}$ and ó$^{2}_{D}$, in the expression of cob weight plant^{-1} and grain yield plant^{-1}. However, magnitude of ó$^{2}_{D}$ was higher than that of ó$^{2}_{A}$ in the expression of ASI and seed yield plant^{-1}; the converse is true for cob weight plant^{-1}. Nevertheless, selection of inbred lines during F_4 generations would be expected to be effective as there would be substantial increase in homozygote's and hence the impact of ó$^{2}_{D}$ are fixed in homozygous lines. The results are in conformity with those of Makumbi *et al.* (2011) and Ertiro *et al.* (2013).

Relationship of hybrid per se performance with sum of parental gca effects: Relatively high magnitude of correlation between sum of the parental *gca* effects with hybrid per se performance for all the traits (Fig. 4, 5, 6), suggested that parental *gca* effects

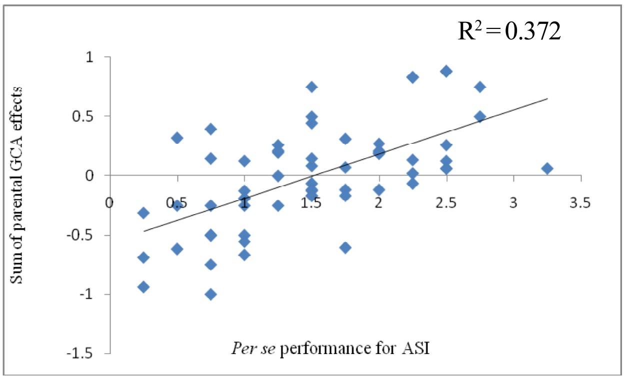

Fig.4: Correlation of hybrid per se performance with sum of parental gca *effects for ASI*

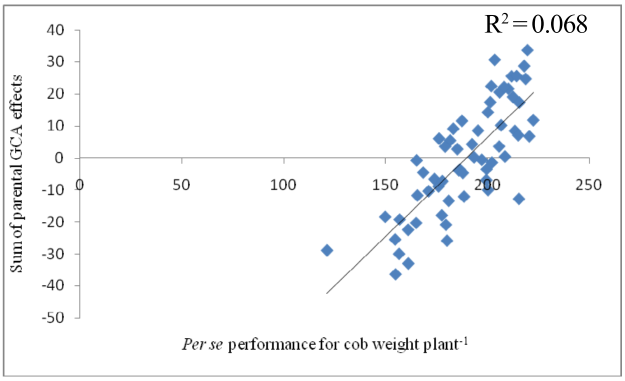

Fig. 5: Correlation of hybrid per se performance with sum of parental gca *effects for cob weight plant*$^{-1}$

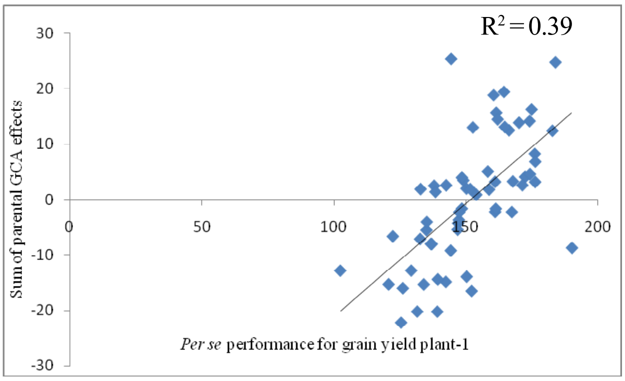

Fig. 6: Correlation of hybrid per se performance with sum of parental gca *effects for grain yield plant*$^{-1}$

retained fairly high predictability of hybrid per se performance. Detection of considerable magnitude of ó^2_A (Table 3) reinforces the predictability of the hybrids performance based on their parental *gca* which is attributable to additive effect genes (Falconer and Mackay, 1996). Prediction of hybrid heterosis based on parental *gca* effects would save substantial

TABLE 3

Estimates of components of genotypic variance for quantitative traits

Trait	Additive genetic variance (ó^2_A)	Dominance genetic variance (ó^2_D)	ó^2_A / ó^2_D
ASI (days)	00.06	00.18	00.37
Cob weight plant^{-1} (g)	382.64 **	237.95 **	01.60
Grain yield plant^{-1}(g)	150.85 **	238.79 **	00.63

*Significant at P=0.05; ** Significant at P=0.01

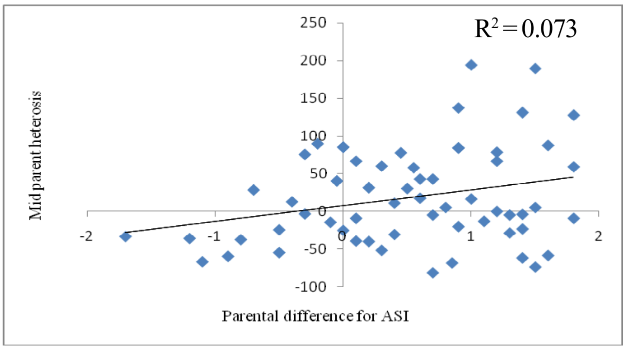

Fig. 7: Correlation of parental difference with mid parent heterosis for ASI

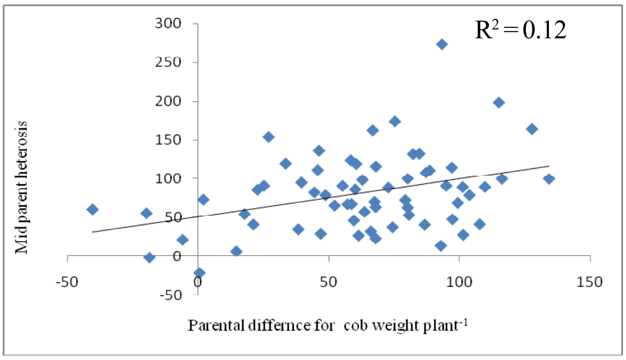

Fig. 8: Correlation of parental difference with mid parent heterosis for cob weight plant^{-1}

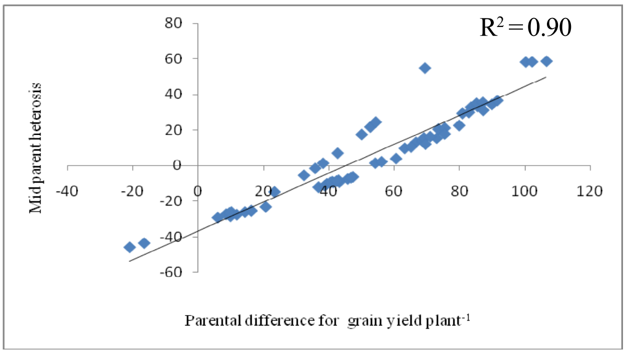

Fig. 9: Correlation of parental difference with mid parent heterosis for grain yield plant^{-1}

resources and time in terms of evaluation of only a few hybrids that are predicted to be most promising ones. The utility of parental *gca* effects for predicting hybrid per se performance has also been reported by Schrag *et al.* (2009).

Relationship of parental genetic difference with heterotic status: A fairly high magnitude of correlation between parental difference and MPH for grain yield plant^{-1} (Fig. 9) indicated that higher the parental diversity, higher will be the heterosis. Remaining two traits (Fig. 7 & 8) attributed lower magnitude of correlation. These results suggest the need for involving diverse parents for realizing high frequency of heterotic hybrids. These results also provide empirical evidence for the theoretical concepts for the requirements of parental diversity for realizing heterotic hybrids. Similar results were reported by Falconer and Mackay (1996).

References

AI-ZHI, L. V. AND ZHENG, Y., 2012, Conversion of the statistical combining ability into a genetic concept. *J. Integrative agric.,* **11** (1) : 43 - 52.

ALI, F., MUNEER, M., RAHMAN, H., NOOR, M., DURRISHAHWAR, SHAUKAT, S. AND YAN, J. B., 2011, Heritability estimates for yield and related traits based on testcross progeny performance of resistant maize inbred lines. *J. Food Agric. Environ.*, **9** : 438 - 443.

BERNARDO, R., 2010, *Breeding for Quantitative traits in Plants*. Second Edition, Stemma press, Woodbury, Minnesota, UAS.

El-Hosary, A. A. A., 2014, Relative values of three different testers in evaluating combining ability of new maize inbred lines. *Int. J. Plant Breeding Genet.*, **8** (2) : 57 - 65.

ERTIRO, B. T., ZELEKE, H., FRIESEN, D., BLUMMEL, M. AND TWUMASI, A. S., 2013, Relationship between the performance of parental inbred lines and hybrids for food-feed traits in maize (*Zea mays* L.) in Ethiopia. *Field crop Res.,* **153** : 86 - 93.

FALCONER, D. S. AND MACKAY, T. F. C., 1996, *Introduction to Quantitative Genetics.* Addison Wesley Longman Limited, London.

FASAHAT, P., RAJABI, A., RAD, J. M. AND DERERA, J., 2016, Principals and utilization of combining ability in plant breeding. *Biom. Biostat. Int. J.,* **4** (1) : 1 - 24.

KANAGARASU, S., NALLATHAMBI, G. AND GANESAN, K. N., 2010, Combining ability analysis for yield and its component traits in maize (*Zea mays* L.). *Electronic J. Plant Breed.*, **1** (4) : 915 - 920.

KEMPTHORNE, O., 1957, *An Introduction to Genetic Statistics*. John Willey and Sons, Inc., New York.

MAKUMBI, D., BETRAN, F. J., BANZINGER, M. AND RIVAUT, J., 2011, Combining ability, Heterosis and genetic diversity in tropical maize (*Zea mays* L.) under stress and non-stress conditions. *Euphytica*, **180** (2) : 143 - 162.

MANPREET, B., SITAR, S., ANIL, K., MANOJ, K., JAY, P. AND ASHISH, N., 2007, Combining ability analysis and heterosis estimates in high quality protein maize inbred lines. *Indian J. Agric. Res.,* **41** (1) : 49 - 53.

SCHRAG, T. A., FRISCH, M., DHILLON, B. S. AND MELCHINGER, A. E., 2009, Marker based prediction of hybrid performance in maize single crosses involving doubled haploids. *Maydica*, **54** : 353 - 362.

SPRAGUE, G. F. AND TATUM, L. A., 1942, General vs. specific combining ability in single crosses of Corn. *Agron. J.,* **34** : 923 - 932.

TURNER, J. K., 1953, A study of heterosis in upland cotton and combining ability and inbreeding effects. *Agron. J.*, **45** : 487 - 490.

(*Received :* May, 2018 *Accepted :* July, 2018)