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ORIGINAL ARTICLE

Combining Ability Analysis in Early Duration Maize Inbred Lines

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ABSTRACT
Ten diverse inbred lines were mated through a half diallel mating design during Kharif-2012 and Rabi 2012-13 at Dryland (Karewa) Agriculture Research Station, Budgam and AICRP Winter Maize Nursery, Hyderabad, respectively. The parents and their all possible F_1 crosses excluding reciprocals, were evaluated in the Randomized Complete Block Design (RCBD) with two replications at two locations viz., Srinagar and Budgam. Substantial genetic variability in the crosses was reflected by highly significant differences among the parents and their crosses for all the traits in the individual environments and data pooled over environments. The significance of the variances resulting from gca x environments and sca x environments pointed out that gca and sca effects also exhibited interaction with environments for all the traits. Magnitude of dominance variance was higher in range in the individual environments as well as data pooled over environments for all the traits, indicating preponderance of non-additive gene action.
Keywords: Randomized Complete Block Design, Maize Inbred Lines

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INTRODUCTION

Maize (called corn in some countries) is a cereal crop, grown widely throughout the world in a range of agro-ecological environments that include tropics, sub-tropics and temperate regions; from sea level to 3000 m above both under irrigated to semi-arid conditions. Having originated in Mexico, maize is now grown at least in 164 countries around the world and a tremendous choice is available as regards varieties maturing in 85 days to more than 200 days with variability in grain colour, size and texture. More maize is produced annually than any other grain, and at global level production was 854.6 million tons from 168.4 million hectares with a productivity of 5.07 tons per hectare followed by wheat (691 million tons) and rice (461 million tons) [1-3]. This represents 38% of the total grain production as compared to 30% for wheat and 20% for rice. Maize is a very important cereal in many developed and developing countries of the world. It is widely used for food, feed, fodder, as an industrial raw material, and for ethanol production. Maize statistics of Jammu and Kashmir reveals that the crop is grown on an area of 0.32 million hectares with an annual production of 0.66 million tons and an average productivity of 2.14 tons per hectare (Anonymous, 2014b). The choice of parents on the basis of *per se* performance, irrespective of adopting participatory or non-participatory plant breeding approach, does not provide clear information on genetic architecture and genetic parameters such as combining ability of parents, and nature and extent of gene action for important traits. These have been found to be useful tools in selection of parents, and when used in a planned hybridization programme are likely to give successful results.

MATERIALS AND METHODS

Ten diverse inbred lines of maize (*Zea maize* L.) viz., KDM-361A, KDM-343A, KDM-332A, KDM-914A, KDM-895A, KDM-340A, KDM-362A, KDM-916A, CM-128 and CM-502 were selected from the germplasm collection maintained at Dryland (*Karewa*) Agriculture Research Station, SKUAST-Kashmir, Budgam and used as base material for the present study these lines were primarily identified on the basis of genetic variability for yield attributing traits and maturity.

Forty five F_1 crosses (excluding reciprocals) were generated through a 10×10 diallel mating design during *Kharif* 2014 and *Rabi* 2014-15 at experimental farm of Dryland Agriculture Research Station, SKUAST-Kashmir, Budgam and Winter Maize Nursery (IIMR), Rajendranagar, Hyderabad. The 45 crosses so developed (through controlled hand pollination) were evaluated along with their parents (10 inbred lines) at two different locations i.e., Shalimar (E_1) and Budgam (E_2) during *Kharif*-2015. Observations were recorded on morphological traits viz. days to 50 % tasseling, 50 % silking, days to 75% husk browning., plant height, cob height, cob length (cm), cobsper plant., number of kernel rows per cob, number of kernels per row, cob diameter (cm)., hundred seed weight (g) and grain yield per plant (g). Diallel component analysis was performed with the help of statistical software Windostat version 9.1

RESULTS AND DISCUSSION

The knowledge of combining ability effects of parents and crosses together with their *per se* performance is of paramount importance to a breeder for identification of desirable genotypes and selection of an appropriate methodology for handling the segregating generations. The present investigation focused on handling early generation bulks in maize, primarily involving this information to help identify populations for a participatory varietal selection programme. The materials obtained could also be handled through conventional breeding programme for identification of promising composite varieties. Many studies using Griffing's analysis have shown that *per se* performance of the parents are often associated with their combining ability because of unpredictable potency of parents [15]. Singh and Gupta [16] suggested that the parents of different genetic background, also affected by complex gene interactions, influence the direction of F_1 expression. The situation becomes more unpredictable for F_1 performance when non-allelic interactions increase upon hybridity [18]. The general and specific combining ability of the parents and the crosses, respectively were therefore estimated, to generate information on the nature of the effects and their role in the selection breeding programme.

The GCA effects, as is well known, represent the additive nature of gene action. A high general combiner parent is characterized by its better breeding value when crossed with a number of other parents. Depending upon the character concerned the nature (direction/sign) and *per se* (mean) performance of the parents is also considered in association with GCA since the former offers reliability and authenticity to GCA as a guide to selection of the parent. Further the GCA variance (σ^2g) of parent and SCA variance (σ^2s) of the cross plays a significant role in making the choice of parents. Therefore, general combining ability effects of ten inbred lines were estimated to know their genetic worth for use in identification of superior progenies. The estimates of GCA effects of parents (Table 4-4.3), and analysis of the results pooled over environments revealed that none of the parents showed significant GCA effects in the desired direction simultaneously for all the traits. However, estimates of GCA effects of the parents for flowering and maturity traits indicated that among all the parents KDM-332A, KDM-340A and KDM-914A exhibiting highly significant negative desired GCA effects for these traits. KDM-332A was identified as a desirable parent for early maturity and it also showed high combining ability [17] with desirable GCA for rows cob^{-1}, cob length and seed yield plant^{-1}. Zelkike [10] and Khan *et al* [13] highlighted the importance of negative GCA effect for days to 50% tasselling, days to 50% silking and pollen shedding to develop early maturing maize varieties. The relative magnitude of GCA effects revealed that *per se* performance of all maturity traits was generally related to the general combining ability effects. Similar result have been reported by Choudhary *et al.*[12] for days taken to anthesis and in no case late maturity parents were best general combiners.

Estimates of GCA effects for yield and yield attributing traits indicated that KDM-361A, KDM-343A,CM-502 and CM-128 were having significant positive desired GCA effect for 100 seed weight and KDM-332A, KDM-914A, KDM-895A, CM-128 and CM-502 for yield plant^{-1}but CM-502 was a poor combiner for all other traits. High *per se* performance was associated with high general combining ability for these yield traits (Table 4). Poor combiners for these traits was generally associated with low to average performance. Importance of significant positive general combining ability effects for yield contributing traits with high *per se* performance was also reported by Kherha *et al.*[11], Choudhary *et al.*[12], Zelleka [10], Srivastava and Singh [14] and Khan *et al.*[13].The results were further analysed to identify best parents on the basis of gca and *per se* performance for different traits and promising lines are presented in Table 1.

Table-1:Best parents identified on the basis of gca and *per se* performance for different traits in Maize (pooled analysis)

Trait	Parent gca effect	Parent *per se* performance
Plant height (cm)	KDM-340A KDM-343A KDM-332A CM-128	KDM-343A KDM-332A KDM-914A KDM-895A
Ear height (cm)	KDM-340A KDM-914A KDM-332A	KDM-332A KDM-895A KDM-361A KDM-340A KDM-914A
Days to 50% tasseling	KDM-332A KDM-914A KDM-340A CM-128	KDM-332A KDM-895A KDM-362A KDM-340A KDM-916A
Days to 50% silking	KDM-332A KDM-914A KDM-916A CM-128	KDM-332A KDM-895A KDM-914A KDM-343A KDM-362A
Days to 75% husk browning	KDM-332A KDM-914 KDM-362	KDM-362A KDM-916A KDM-343A KDM-340A KDM-914A
Cob length (cm)	KDM-361A KDM-343A KDM-332 CM-128	KDM-361A KDM-343A KDM-914A KDM-895A CM-128
Cobs plant^{-1}	KDM-343A KDM-914A KDM-362 CM-502	KDM-343A KDM-340A KDM-916A KDM-362A KDM-361A
Rows cob^{-1}	KDM-332A KDM-340A KDM-895	KDM-340A KDM-343A KDM-916A CM-502 CM-128
Grains row^{-1}	KDM-343 KDM-332 KDM-340A CM-128	KDM-343A KDM-340A KDM-914A CM-128 KDM-895A
Cob diameter (cm)	KDM-332A KDM-340A KDM-343	KDM-340A KDM-361A CM-128 CM-502 KDM-916A
100-seed weight (g)	KDM-361A KDM-343A KDM-916 CM-128 CM-128	KDM-340A KDM-916A CM-502 CM-128 KDM-343A
Yield plant^{-1} (g)	KDM-914A KDM-332 CM-128 CM-502	KDM-340A KDM-343A CM-128 CM-502 KDM-914A

As none of the parents was a good general combiner for all the traits studied, the parents with desirable GCA for maximum traits could be utilized for development of elite bulk populations by allowing thorough mixing to achieve new genetic recombination's and then subjecting them to recurrent selection. However gca effects need also be considered in breeding programme. The estimates of specific combining ability effects of the 45 crosses for various traits revealed that none of the cross combinations possessed high SCA effects for all the traits. However, crosses which exhibited significant and desirable SCA effects included KDM-343 x CM-128, DM-332 x CM-502, KDM-340 x KDM-362, KDM-340 x KDM-916 for plant height. KDM-332 x CM-502, KDM-340 x KDM-362, KDM-340 x KDM-916, KDM-340 x CM-128 for ear height; KDM-361 x KDM-332, KDM-361 x CM-128, KDM-914 x KDM-916, KDM-362 x KDM-916, DM-340 x CM-502, and CM-128 x CM-502 for days to 50% tasseling; KDM-361 x KDM-340, KDM-361 x CM-128, KDM-914 x KDM-916, KDM-362 x KDM-916 days to 50% Silking. KDM-361 x CM-128, KDM-332 x KDM-340, KDM-914 x CM-128, KDM-362 x CM-502 days to 75% husk browning; KDM-914 x KDM-128, KDM-343 x KDM-914, KDM-332 x CM-502, KDM-362 x CM-502, KDM-361 x KDM-916, KDM-361 x CM-128, KDM-361 x CM-502, KDM-343 x KDM-914 for cob length; KDM-914 x KDM-362, KDM-361 x CM-128, KDM-914 x CM-128, KDM-916 x CM-502, KDM-916 x CM-128, Cobs Plant^{-1}; KDM-361 x KDM-332, KDM-361 x KDM-914, KDM-361 x KDM-895, KDM-361 x KDM-340, KDM-340 x KDM-916, KDM-362 x CM-128, KDM-362 x CM-502. for rows cob^{-1}; KDM-914 x CM-128, KDM-362 x CM-502, KDM-343 x KDM-914, KDM-332 x KDM-502, KDM-36 x KDM-362, KDM-361 x KDM-916, KDM-361 x CM-128, KDM-361 x CM-502, CM-128 x CM-502 for grains row-^{1}; KDM-343 x KDM-914, KDM-361 x CM-128, KDM-343 x KDM-895, KDM-332x KDM-340 for cob diameter; KDM-361 x KDM-332, KDM-361 x CM-128, KDM-361 x CM-502, KDM-343 x KDM-914, KDM-914 x CM-128, KDM-914 x CM-502, KDM-895 x KDM-340 for 100 seed weight ; KDM-361 x CM-128, KDM-332 x KDM-340, KDM-343 x KDM-914, KDM-362 x CM-502, KDM-895 x CM-128, KDM-895 x CM-502 for seed yield plant^{-1}.

Uddin *et al.* [19] and Khan *et al* [13] in separate studies on combining ability analysis in maize reported that GCA and SCA effects were highly significant in the desired negative direction for maturity traits (days to 50%silking, days to 50% tasselling and days to pollen shedding) and in desired positive direction for yield and yield contributing traits (kernel rows cob^{-1},cob length, kernels row^{-1}, 100 seed weight and yield plant^{-1}). Similar results were also reported from the studies of Ojo *et al.* [7], Vasal *et al.* [8] and Zivanovic *et al.* [9] in maize. While assessing the performance of parents on the basis of their general combining ability and their role in various cross combinations, it was observed that most of the desirable specific cross combinations were the result of crosses between high x low or high x average or low x average general combiners. None of the cross combinations, however, revealed superiority for all the traits studied. Promising cross combinations for various traits on the bases of desirable sca and gca effects of the parents are given in Table 2. The perusal of results indicated that superior crosses for different traits involved all types of combiners, however no desirable specific cross combination was resulted from low x low general combiners. Our results are in conformity with the very early studies of Cowan [4] and Dass *et al.*[5] that low x low combiners yielded distinctly less than high x high, high x average and average x average combiners. Their studies also revealed that good cross combination is not always result of high x high general combiners. The superiority of crosses involving high x high, high x average and average x average combiners as parents might, therefore, have possibly resulted from the concentration and interaction of favourable alleles contributed by parents. The superiority of crosses involving high x low or average x low combiners as parents could be due to interaction between positive alleles from good/average combiners and negative alleles from the poor combiners as parents [6].

Table-2:Top ranking specific cross combinations for different traits on the basis of sca, *per se* performance and gca of parents involved in Maize (Pooled Analysis)

S. No.	Trait	*per se* performance	sca effect	gca effect of parents
1	Plant Height (cm)	KDM-361A x KDM-916A KDM-361A x CM-128 KDM-332A x KDM-916A KDM-914A x KDM-362A	KDM-343A x CM-128 KDM-340Ax KDM-916A KDM-340Ax KDM-362A KDM-332A x CM-502	High x High High x Avg. High x Avg. High x Avg.
2	Ear height (cm)	KDM-361A x KDM-916A KDM-361A x CM-128 KDM-332A x KDM-916A KDM-895A x KDM-916A	KDM-340A x KDM-916ª KDM-332A x CM-502 KDM-340A x CM-128 KDM-340A x KDM-362ª	High x Avg. High x Avg. High x Avg. High x Avg.
3	Days to 50% Tasseling	KDM-361A x KDM-332A KDM-361A x CM-128 KDM-914A x KDM-916A KDM-914A x CM-128	KDM-362A x KDM-916ª KDM-914A x KDM-916A KDM-361A x CM-128 CM-128 x CM-502	Avg. x Low High x Low Low x High High x Avg.
4	Days to 50% Silking	KDM-361A x KDM-332A KDM-343A x KDM-914A KDM-362A x KDM-916A CM-128x CM-502	KDM-361A x CM-128 KDM-362A x KDM-916A KDM-361A x KDM-340A KDM-914A x KDM-916A	Low x Avg. Avg.x Low Low x Avg. High x Low
5	Days to 75% Husk Browning	KDM-361A x KDM-332A KDM-361A x CM-128 KDM-332A x KDM-340A KDM-914A x KDM-362A	KDM-361A x CM-128 KDM-332A x KDM-340 KDM-914A x CM-128 KDM-362A x CM-502	Avg. x Avg. High x Avg. High x Avg. High x Avg.
6	Cob Length (cm)	KDM-361A x CM-128 KDM-914A x CM-128 KDM-332A x CM-502 KDM-343A x KDM-914	KDM-914A x CM-128 KDM-343A x KDM-914A KDM-332A x CM-502 KDM-362A x CM-502	Avg. x High High x Avg. High x Avg. Avg. x Avg.
7	Cobs plant^{-1}	KDM-914A x KDM-340A KDM-343A x CM-502 KDM-332A x CM-502 KDM-916A x CM-502	KDM-914A x KDM-362A KDM-361A x CM-128 KDM-914A x CM-128 KDM-916A x CM-502	High x High Low x Low High x Low Low x High
8	Rows cob^{-1}	KDM-361A x KDM-332A KDM-343A x CM-128 KDM-332A x KDM-340A KDM-340A x KDM-916A	KDM-340Ax KDM-916CA KDM-343A x CM-128 KDM-361A x KDM-332A KDM-362A x CM-502	High x Low High x Avg. Low x Avg. High x High
9	Grains row^{-1}	KDM-343A x KDM-914A KDM-332A x CM-502 KDM-914A x CM-128 KDM-362A x CM-502	KDM-914A x CM-128 KDM-362A x CM-502 KDM-343A x KDM-914A KDM-332A x CM-502	Avg. x High Avg. x Avg. High x Avg. High x High
10	Cob diameter (cm)	KDM-361A x KDM-332A KDM-361A xCM-128 KDM-343A x KDM-914A KDM-332A x KDM-340A	KDM-343A x KDM-914A KDM-361A x CM-128 KDM-343A x KDM-895A KDM-332A x KDM-340	High x Avg. Low x Low High x Low High x High
11	100 Seed Weight (g)	KDM-361A x KDM-332A KDM-361A x KDM-343A KDM-361A x CM-128 KDM-343A x KDM-914A	KDM-361 x KDM-332 KDM-361A x CM-128 KDM-343A x KDM-914A KDM-914A x CM-128	High x Low High x High High x Avg. Avg. x High
12	Yield Plant^{-1} (g)	KDM-361A x CM-128 KDM-343A x KDM-914A KDM-332A x KDM-340A KDM-362A x CM-502	KDM-361A x CM-128 KDM-332A x KDM-340A KDM-343A x KDM-914A KDM-362 x CM-502	Avg. x High Avg. x Avg. Avg. x High Avg. x High

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