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**Original Research Article**

# Evaluation of Inbred Lines for Combining Ability in Maize (*Zea mays* L.)

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**A B S T R A C T**

Thirty $F_1$ crosses developed from six parents in full diallel mating fashion were evaluated in Randomised Block Design along with six parents and two checks Rajarshri and PKVM-Shatak to estimate the general combining ability of parents, specific combining ability and reciprocal combining ability of crosses and to identify potential $F_1$'s for advancing in further. The mean squares due to general combining ability were significant for all the characters studied. The mean squares due to specific and reciprocal combining ability were significant for all characters. The three parents, NAUM-21, NAUM-8 and DC-7 were identified as best general combiner for yield and other yield contributing characters. These genotypes were recommended for their use in the crossing program or for developing gene pool. Only one cross DC-3 x DC-7 exhibited significant positive combining ability for grain yield plant$^{-1}$, days to 50% tasseling, days to 50% silking, days to maturity, Plant height (cm), cob girth (cm), number of grains cob$^{-1}$, 100 grain weight and grain yield plot$^{-1}$ was identified as the potential cross. Hence, it is suggested that the parents identified could be utilized for the development of either the synthetic varieties or elite breeding population and the one cross identified could be directly used for heterosis breeding in maize.

**Keywords**

Diallel, gca effect, sca effect and combining ability, Maize

## Introduction

Maize (*Zea mays* L.) is the third most important cereal grain in the world after wheat and rice. Maize being a cross-pollinated crop there is wide scope for the development of single cross hybrids and varieties. In recent years, there has been a perceptible improvement in maize production in the state, but production and productivity of India is much less than country like, U.S.A.

The varieties/hybrids, which are cultivated in the recent years, are not stable. Therefore, there is a need to have stable inbred lines, which can help in the development of single cross hybrids/varieties.

Selection of suitable parents for crossing is the first and foremost step in making any sort of improvement. The plant breeders use the techniques of many biometrical approaches like, diallel, line x tester, top cross and poly cross to choose appropriate parents. Of these diallel analysis is one of the efficient, convenient and often used biometrical tool that provides information on the parents from the study of $F_1$ itself. This is widely employed in estimating the extent of general combining ability of the parents and specific combining ability of their hybrids and is useful to assess the nature of inheritance of a character. With this perspective, the present study is planned using diallel analysis mating design in maize.

## Materials and Methods

During *rabi* 2015-16, 30 crosses were obtained by crossing 6 genotypes in full diallel mating design. Crossed seeds of these 30 crosses along with 6 parents and checks (Rajarshri and PKVM-Shatak) had been sown in randomized block design with 3 replications in *kharif* 2016-17 for evaluation with a spacing 60 cm x 20 cm at the experimental farm of Botany section, College of Agriculture, Nagpur in *kharif* 2016 for evaluation. Observations were recorded on randomly five plants grown on days to 50% tasseling, days to 50% silking, days to maturity, plant height (cm), cob girth (cm), cob length (cm), number of grains cob$^{-1}$, 100 grain weight (g), grain yield plant$^{-1}$ (g), and grain yield plot$^{-1}$ (kg). The data were subjected to the statistical and biometrical analyses suggested by Panse and Sukhatme (1954). The combining ability analysis was carried out following the methodology of Diallel Method-1 (Model-l) given by Griffing (1956).

## Results and Discussion

Analysis of variance for combining ability for all ten characters is presented in table 1**.** The variation among the crosses was partitioned into different components representing due to gca, sca and rca. The mean squares due to general combining ability were significant for all the 10 characters under study. The mean squares due to specific and reciprocal combining ability were significant for all the 10 characters. The mean square for gca were of higher magnitude than those of sca in all the characters studied. It indicated that both gca and sca played significant role in the expression of these traits. The significant mean squares due to sca were also reported by Prasad and Singh (1986), Zelleke (2000), Kabdal *et al.*, (2003), Aliu *et al.*, (2008) and Mohammad *et al.*, (2013) in maize. Prasad and Singh (1986) in maize also showed significant mean square of rca for characters like days to 50% tasseling, days to 50% silking, days to maturity, plant height (cm), cob girth, cob length, number of grains cob$^{-1}$, 100 grain weight, grain yield plant$^{-1}$ and grain yield plot$^{-1}$.

Combining ability effects (gca, sca and rca effect) are presented in table 2. Among the parents DC-7, NAUM-8 and NAUM-14 showed significant positive gca effect and were found to be good combiner parents for days to 50% tasseling. Among the direct crosses, two crosses showed positive significant sca effect in which the cross DC-3 x NAUM-21 exhibited highest positive sca effect followed by DC-7 x NAUM-21. Among the reciprocal crosses, four crosses showed positive significant rca effect. The cross NAUM-14 x DC-3 and NAUM-21 x 14 (3.83) exhibited highest positive rca effect followed by DC-3 x DC-7 and NAUM-8 x DC-7. Kumar *et al.*, (2014) and Niyonzima *et al.*, (2015) have reported similar results.

Among the six parents, NAUM-14 was found to be good combiner followed by NAUM-8 and DC-7 for days to 50% silking. Fifteen direct crosses showed significant sca effect, out of which six crosses showed positive sca effect. The cross DC-3 x NAUM-21 exhibited highest positive sca effect followed by DC-7 x NAUM-14, DC-3 x NAUM-26 and DC-7 x NAUM-26 for days to 50% silking. Nine crosses showed significant rca effect for days to 50% silking, out of which seven crosses showed positive rca effects. The cross NAUM-14 x DC-3 exhibited highest positive rca effect followed by NAUM-21 x NAUM-14, DC-3 x DC-7 and NAUM-8 x DC-7. Kumar *et al.,* (2014) and Niyonzima *et al.,* (2015) have reported similar results.

Among the parents, NAUM-8, DC-3, DC-7, NAUM-26 and NAUM-21 were found to be good combiner for days to maturity. Nine crosses showed significant sca effect out of which two crosses NAUM-26 x NAUM-21 and NAUM-26 x NAUM-14 were in positive direction. Seven crosses showed significant rca effect, out of which five crosses were in positive. The cross NAUM-141 x DC-3 exhibited highest positive rca effect followed by NAUM-21 x NAUM-14 and NAUM-21 x NAUM-8 for days to maturity. Kumar *et al.,* (2014) and Niyonzima *et al.,* (2015) have reported similar results.

Among the parents, four parents NAUM-8, NAUM-21, DC-3 and DC-7 exhibited highly significant gca effect in the desirable direction and were good combiners for plant height. Fourteen crosses showed significant sca effect, in which five crosses showed positive sca effect. Highest positive sca effect was recorded in cross NAUM-26 x NAUM-14 followed by DC-7 x NAUM-14 and DC-3 x NAUM-26. Eleven crosses showed positively significant rca effect, out of which cross NAUM-21 x DC-7 exhibited highest positive rca effect followed by NAUM-21 x DC-3 and NAUM-21 x NAUM-8. Kumar *et al.*, (2009) and Kumar *et al.*, (2014) have reported similar results.

For cob girth only the parents NAUM-21 was found to be good combiner. Four crosses showed significant sca effect, out of which only the cross DC-3 x NAUM-21 showed positive sca effect. Highly significant positive rca effect was observed in the cross NAUM-21 x NAUM-14. Prasad *et al.,* (1987), Kumar *et al.,* (2013) and Niyonzima *et al.*, (2015) have reported similar results.

Among the parents NAUM-21 recorded significant gca effect in the desirable direction while DC-3 was poor combiner for cob length. Positive significant sca effect were observed in three crosses in which DC-3 x NAUM-21 exhibited highest positive sca effect followed by DC-7 x NAUM-14 and DC-7 x NAUM-8.

Seven crosses showed significant rca effect in positive direction. Highest positive rca effect was reported in the cross DC-3 x DC-7 followed by cross NAUM-14 x DC-7 (2.13 cm) and NAUM-14 x NAUM-26. Kumar *et al.,* (2013) and Niyonzima *et al.,* (2015) have reported similar results.

**Table.1** Analysis of variance for combining ability

| Sources of variation | Degrees of freedom | Mean squares | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Days to 50% tasseling** | **Days to 50% silking** | **Days to maturity** | **Plant height (cm)** | **Cob length (cm)** | **Cob girth (cm)** | **Number of grains cob$^{-1}$** | **100 grain weight (g)** | **Grain yield plant$^{-1}$ (g)** | **Grain yield plot$^{-1}$ (kg)** |
| **GCA** | 5 | 10.32** | 8.33** | 73.11** | 461.58** | 10.80** | 1.03** | 10092.15** | 10.49** | 460.02** | 0.086** |
| **SCA** | 15 | 6.30** | 6.97** | 32.68** | 273.33** | 5.17** | 0.57** | 3188.45** | 7.59** | 273.91** | 0.048** |
| **RCA** | 15 | 7.84** | 7.71** | 31.95** | 151.19** | 3.38** | 0.46** | 3731.28** | 9.01** | 387.78** | 0.066** |
| **Error** | 70 | 2.53 | 0.30 | 2.32 | 3.87 | 0.64 | 0.10 | 14.16 | 2.87 | 2.08 | 0.0027 |

*, ** = significant at 5% and 1% level respectively.

# = The degrees of freedom is only 70 as check (Rajeshi and PKVM-Shatak) is not included in the analysis

**Table.2** Gca effects of parents, sca effect of crosses and rca effect of reciprocals

| Sr. No | Parents | Days to 50% tasseling | Days to 50% silking | Days to maturity | Plant height (cm) | Cob girth (cm) | Cob length (cm) | No of grains cob$^{-1}$ | 100 grain weight (g) | Grain yield plant$^{-1}$ (g) | Grain yield plot$^{-1}$ (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **gca** | | | | | | | | | | |
| 1 | DC-7 | 2.31** | 1.67* | 3.44** | 13.09** | 0.06 | -0.10 | 19.75** | 0.29 | -8.20** | -0.02 |
| 2 | DC-3 | -2.29** | -2.76** | 5.88** | 13.52** | -0.42 | -1.72* | -34.22** | 2.62** | -6.03** | -0.09 |
| 3 | NAUM-8 | 2.25** | 2.23** | 8.50** | 23.61** | 0.70 | 1.46 | 53.83** | 1.83* | 23.23** | 0.40** |
| 4 | NAUM-26 | -0.85 | -0.32 | 2.38** | -3.11** | 0.27 | 0.67 | -20.80** | -0.96 | -7.73** | -0.13 |
| 5 | NAUM-14 | 1.59* | 2.56** | 2.00* | -2.91** | 0.09 | 0.78 | -31.56** | 0.69 | -8.76** | -0.08 |
| 6 | NAUM-21 | 0.09 | -0.76 | 2.11** | 18.38** | 2.02* | 1.75* | 70.86** | 3.98** | 27.76** | 0.39** |
| | **Direct cross** | **sca** | | | | | | | | | |
| 7 | DC-7 X DC-3 | -1.49 | -1.38** | 0.50 | -17.39** | -0.11 | -1.81** | -22.13** | -3.27** | -1.50 | -0.01 |
| 8 | DC-7 X NAUM-8 | -2.21* | -2.21** | 1.47 | 5.92** | 0.21 | 1.517** | 23.52** | 0.49 | 7.39** | -0.006 |
| 9 | DC-7 X NAUM-26 | 0.56 | 1.34** | -2.91** | -7.88** | 0.20 | 0.75 | 10.91** | 2.19* | 12.36** | 0.16** |
| 10 | DC-7 X NAUM-21 | 2.12* | -1.54** | -2.72** | -6.73** | -0.7** | -2.80** | -78.12** | -1.83 | -19.98** | -0.21** |
| 11 | DC-7 X NAUM-14 | -1.29 | 2.12** | 0.22 | 12.98** | 0.38 | 2.44** | 46.06** | 2.12 | 9.94** | 0.10** |
| 12 | DC-3 X NAUM-8 | 0.81 | 0.89* | 1.02 | -3.69** | 0.10 | 0.70 | -14.42** | 0.39 | -5.32** | -0.03 |
| 13 | DC-3 X NAUM-26 | 1.59 | 1.95** | -3.69** | 10.17** | 0.42* | 0.11 | -3.27 | -0.50 | 0.66 | 0.04 |
| 14 | DC-3 X NAUM-21 | 3.23** | 3.23** | 0.83 | 3.28* | - 0.26 | 2.65** | 71.95** | 1.83 | 13.83** | 0.13** |
| 15 | DC-3 X NAUM-14 | -1.85 | -1.93** | -4.55** | -5.89** | 0.26 | 0.06 | 2.10 | -1.07 | -1.63 | -0.027 |
| 16 | NAUM-8 X NAUM-26 | -0.46 | -1.21** | -6.55** | -13.95** | - 0.54* | -1.32* | -19.28** | -1.73 | -7.18** | -0.11** |
| 17 | NAUM-8 X NAUM-21 | 0.84 | 1.23** | -4.19** | -3.26* | - 0.40 | -0.78 | -35.58** | -0.52 | -15.36** | -0.18** |
| 18 | NAUM-8 X NAUM-14 | -1.24 | -0.93* | -0.25 | -8.61** | - 0.08 | -1.57** | -8.06** | -0.47 | -2.75** | -0.05 |
| 19 | NAUM-26 X NAUM-14 | 0.70 | -0.71* | 4.69** | 15.44** | - 0.21 | -0.56 | 26.51** | 1.59 | 5.66** | 0.12** |
| 20 | NAUM-26 X NAUM-21 | -1.54 | -1.04** | 6.08** | -0.66 | - 0.15 | 0.350 | 5.93* | -0.59 | -3.78** | -0.07* |
| 21 | NAUM-14 X NAUM-21 | -1.32 | -1.10** | -2.11* | -11.00** | - 0.44* | -1.16* | -35.05** | -2.86* | -2.46* | -0.05 |
| | **Reciprocal crosses** | **rca** | | | | | | | | | |
| 22 | DC-3 X DC-7 | 3.33** | 3.16** | 4.16** | 5.40** | 0.70* | 2.26** | 107.86** | 4.83** | 13.60** | 0.18** |
| 23 | NAUM-8 X DC-3 | -1.50 | -0.83* | -0.66 | 0.60 | -0.6** | 1.13* | -21.03** | -0.43 | -5.56** | -0.11** |
| 24 | NAUN-8 X DC-7 | 3.00** | 2.83** | -3.33** | -12.33** | -0.12 | 0.83 | -3.03 | -1.46 | -11.01** | -0.04 |
| 25 | NAUM-26 X NAUM-8 | -1.50 | 1.16** | -1.50 | 8.10** | -0.10 | -0.16 | -16.90** | -0.40 | 1.33 | -0.06 |
| 26 | NAUM-26 X DC-7 | 1.16 | 0.66 | 1.16 | 8.10** | -0.7** | 0.50 | -16.90** | -2.73* | -20.13** | -0.27** |
| 27 | NAUM-26 X DC-3 | -0.33 | -0.50 | -1.16 | 4.06** | 0.30 | -0.23 | 54.66** | 1.76 | 26.73** | 0.40** |
| 28 | NAUM-14 X NAUM-8 | -0.16 | -0.50 | 1.16 | 3.06* | -0.55* | 1.00 | 5.40* | 0.43 | 3.65** | 0.05 |
| 29 | NAUM-14 X NAUM-26 | -0.83 | 1.00** | -1.33 | 6.60 ** | 0.03 | 1.83** | 19.80** | 0.13 | 7.58** | 0.11** |
| 30 | NAUM-14 X DC-3 | 3.83** | 4.00** | 8.00** | 3.90** | 0.26 | 0.60 | 80.73** | 4.16** | 29.95** | 0.36** |
| 31 | NAUM-14 X DC-7 | 0.33 | 0.50 | 4.00** | 11.96** | 0.03 | 2.13** | 9.80** | 1.16 | 6.96** | 0.13** |
| 32 | NAUM-21 X NAUM-8 | 1.00 | 1.16** | 4.66** | 13.26** | 0.16 | 1.76** | 12.73** | 0.70 | 4.23** | 0.007 |
| 33 | NAUM-21 X NAUM-14 | 3.83** | 3.83** | 5.00** | 0.10 | 0.93** | -0.76 | 29.83** | -1.16 | -6.36** | -0.04 |
| 34 | NAUM-21 X NAUM-26 | -0.66 | -0.50 | -0.50 | 0.10 | -0.6** | 0.40 | -33.06** | -0.86 | -8.86** | -0.14** |
| 35 | NAUM-21 X DC-3 | -0.66 | -0.66 | -1.83 | 14.33** | 0.46* | 1.50** | 26.10** | 2.53* | 16.78** | 0.13** |
| 36 | NAUM-21 X DC-7 | -1.66 | -1.66** | -8.50** | 16.10** | -0.16 | 1.60** | -51.60** | -1.80 | -3.76** | - |
| | **S.E.(gi)** | **0.41** | **0.14** | **0.40** | **0.51** | **0.08** | **0.21** | **0.99** | **0.44** | **0.38** | **0.0137** |
| | **S.E.(sij)** | **0.95** | **0.33** | **0.91** | **1.18** | **0.19** | **0.48** | **2.26** | **1.01** | **0.86** | **0.0314** |
| | **S.E.(rij)** | **1.12** | **0.39** | **1.07** | **1.39** | **0.23** | **0.56** | **2.66** | **1.19** | **1.02** | **0.0369** |

Among the parents NAUM-21, NAUM-8 and DC-7 were observed to be good combiner for number of grains cob$^{-1}$.

Thirteen crosses showed significant sca effect, out of which six crosses showed positive sca effect. The cross DC-3 x

NAUM-21 exhibited highest positive sca effect followed by DC-7 x NAUM-14 and NAUM-26 x NAUM-14. Nine crosses showed significant positive rca effect. The cross DC-3 x DC-7 exhibited highest positive rca effect followed by NAUM-14 x DC-3 and NAUM-26 x DC-3.

Among the six parents, NAUM-21, DC-3 and NAUM-8 recorded significant positive gca effect and parent NAUM-21 was observed to be good combiner for 100 grain weight. Only one cross cross DC-7 x NAUM-26 exhibited significant positive sca effect. Three crosses showed significant positive rca effect, out of which the cross DC-3 x DC-7 exhibited highest positive rca effect followed by cross NAUM-14 x DC-3 and NAUM-21 x DC-3. Prasad *et al.*, (1987), Joshi *et al.*, (1998), Kumar *et al.*, (2013), Kumar *et al.*, (2014) and Niyonzima *et al.*, (2015) have reported similar results.

The parent NAUM-21 and NAUM-8 were good combiner for grain yield plant$^{-1}$. Total twelve crosses showed significant sca effect, in which five crosses were in positive direction. The cross DC-3 x NAUM-21 exhibited highest positive sca effect followed by DC-7 x NAUM-26 and DC-7 x NAUM-14. Prasad *et al.*, (1987) have reported similar results. Significant positive rca effect was reported in eight crosses. The cross NAUM-14 x DC-3 recorded highest positive rca effect followed by NAUM-26 x DC-3 and NAUM-21 x DC-3 for grain yield plant$^{-1}$. Prasad *et al.*, (1987), Beck *et al.*, (1990) Kabdal *et al.*, (2003), Kumar *et al.*, (2009), Kumar *et al.*, (2014) and Niyonzima *et al.*, (2015) have reported similar results.

Among the parents, NAUM-8 and NAUM-21 were good combiner as they recorded significant gca effect in the desirable direction for grain yield plot$^{-1}$. Only four crosses showed highly significant and positive sca effects. The cross DC-7 x NAUM-26 exhibited highest positive sca effect followed by DC-3 x NAUM-21 and NAUM-26 x NAUM-14. Total six crosses showed positive and highly significant rca effect. The cross NAUM-26 x DC-3 exhibited highest positive rca effect followed by NAUM-14 x DC-3 and DC-3 x DC-7. Prasad *et al.*, (1987), Beck *et al.*, (1990), Joshi *et al.*, (1998), Kabdal *et al.*, (2003) and Niyonzima *et al.*, (2015) have reported similar results.

Maize is a highly cross pollinated crop and hence the exploitation of hybrid vigour in maize has gained much significance. Maize being a monoecious crop, it can be exploited to the maximum for commercial hybrid production. Mean performance of the crosses may not indicate the correct superiority of the crosses. Hence the criteria for selecting superior crosses for their exploitation in heterosis breeding should be mean performance of the crosses along with significant heterosis in the desirable direction and positive significant specific combining ability effect and reciprocal combining ability effects. The presence of dominance genetic component in the crosses is the pre requisite for hybrid production. Significant heterosis, positive significant sca and rca effect are the indicators for the presence of dominance.

The results obtained from this study revealed that the estimates of gca, sca and rca effects among the parents and crosses showed wide variation in the level of significance for different characters. Some of the parents and crosses had significant gca, sca and rca effects in the desirable direction for most of the characters studied. The significant gca, sca and rca effects were also reported by Prasad and Singh (1986), Zelleke (2000), Kabdal *et al.*, (2003) and Mir *et al.*, (2015). The estimates of gca effect showed that among the parents NAUM-21 was found to be best general combiner as it recorded significant positive gca effect for days to maturity, plant height (cm), cob girth, cob length, number of grains cob$^{-1}$, 100 grain weight, grain yield plant$^{-1}$ and grain yield plot$^{-1}$. The parents NAUM-8 and DC-7 were also good general combiners as they exhibited significant positive gca effect for early days to 50% tasseling, days to 50% silking, days to maturity, Plant height (cm), cob girth, number of grains cob$^{-1}$, 100 grain weight, grain yield plant$^{-1}$ and grain yield plot$^{-1}$. Therefore, three parents NAUM-21, NAUM-8 and DC-7 were identified as best general combiners for yield and other yield contributing characters.

Out of 30 crosses studied, the crosses showing significant sca effect and rca effect were observed to involve parents with low x high, high x low, high x high and low x low gca effect. Low x high and high x low combiners resulted in crosses with high sca/rca effect which indicated the importance of both additive and dominance genetic interaction.

Low x low general combiners also resulted in some crosses with high sca /rca effect indicated the existence of high dominance variance. The better performing direct crosses in most of the characters did not show similar performance in their respective reciprocal cross which indicated the role of maternal influence.

Out of 15 direct and 15 reciprocal only one cross DC-3 x DC-7 exhibited significant positive combining ability for grain yield plant$^{-1}$, days to 50% tasseling, days to 50% silking, days to maturity, plant height (cm), cob girth (cm), number of grains cob$^{-1}$, 100 grain weight and grain yield plot$^{-1}$. Hence this cross was identified as potential cross for the exploitation in heterosis breeding.

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