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# Combining ability analysis for grain yield and quality characters in pearl millet [*Cenchrus americanus (L.)* Morrone]

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**Abstract**
The objective of the present study is to estimate the combining ability effects among parents and their crosses in pearl millet, to identify promising cross combinations for grain yield and its component traits. In combining ability analysis, the extent of *sca* variance was higher than *gca* variance for all of the characters demonstrating the predominance of non-additive gene action except for panicle length and 1000-grain weight. The estimates of general combining ability suggested that parents, RIB 17 S/109, RIB 16300, RIB 37-40 S/17, RIB 13-16 S/17, ICMA 96666 and ICMA 94111 were good general combiners for yield and its contributing characters. The best hybrid, ICMA 94111 x RIB 16296 involved low x low performing parents which exhibited high positive and significant SCA effect for grain yield and most of the yield contributing and quality traits like protein, iron and zinc. These good combiner lines may be exploited to develop iron and zinc rich hybrids along with grain yield to alleviate malnutrition in people of the country.

**Keywords:** Pearl millet, combining ability, gene action, male sterile line, tester.

## INTRODUCTION

Pearl millet is an important cereal crop in arid and semi-arid region of the world. It is commonly known as Bajra, Cat-tail and Bulrush millet in different parts of the world. It is a diploid species having chromosomes number 2n=14 and belongs to the family Poaceae (Gramineae). In India, Pearl millet is regarded as one of the major source of dietary energy for poor farmers and consumers. It is also an excellent forage crop because of its lower hydrocyanic acid content than sorghum (Yadav *et al.,* 2013). Pearl Millet is rightly termed as "nutri-cereal" as it is a high-energy cereal with high protein, high dietary fiber, free of gluten with higher amounts of iron (Fe) and zinc (Zn). Its grain contains 8.5 to 15 percent protein, 5.03 to 6.0 percent fat, 1.05 to 1.7 percent crude fiber and 65 to 70 per cent carbohydrates. As a food crop, pearl millet grain possesses the highest amount of calories per 100 gram (Burton, 1972) which is mainly supplied by carbohydrates, fats, and protein (Flech, 1981). Its grains have high densities of two most important micro-nutrients *viz*. iron (18 to 135 ppm) and zinc (22 to 92) ppm (Rai *et al*., 2012) for which widespread deficiency in human population had been reported worldwide, including India. Pearl millet is most commonly (>92%) cultivated under rainfed conditions in the arid and semi-arid regions of India where annual rainfall ranges from 150 to 750 mm, most of which is received during June to September.

Because of its cultivation largely in rainfed production systems, pearl millet growth is constrained by several abiotic stresses. Drought is the primary abiotic constraint and is caused by low and erratic distribution of rainfall. Hence, the development of pearl millet cultivars suitable for rainfed and unpredictable low-rainfall situations has been a priority area in crop management. Therefore there is need to identify good parents and superior cross combinations for development of promising hybrids suited to various climatic conditions of the country. The selection of appropriate parents for hybridization programme can be made on the basis of their ability to transmit desirable performance to their progenies. The combining ability analysis helps in the evaluation of inbreds in terms of their genetic value, and in the selection of suitable parents for hybridization. Line × Tester mating design helps in the evaluation of large number of germplasm at a time in terms of variance and effects (Sprague and Tatum, 1942). Keeping these points in view, the present investigation was carried out to study the genetics and heterosis of quality traits for the selection of desired hybrids.

## MATERIALS AND METHODS

Experimental material was developed through crosses between 4 lines (Male sterile lines) *viz*., ICMA 94111, ICMA 96666, ICMA 97111and ICMA 97444 and 10 testers (Restorer lines) *viz*., RI 3135-18, RIB 494, RIB 17 S/109, RIB 16 S/111, RIB 16300, RIB 16296, RIB 17-20 S/17, RIB 33-36 S/17, RIB 37-40 S/17 and RIB 13-16 S/17 in Line × Tester design during Summer, 2019. Subsequently, the resulting 40 $F_1$ crosses along with parents (lines and testers) and standard check (MPMH 17) were evaluated at Mandor (Jodhpur) Rajasthan during *kharif,* 2019. Recommended cultural practices were adopted in order to raise a healthy crop. The observations were recorded on individual plant basis on randomly selected five plants from each replication for 13 characters *viz*; days to 50% flowering, days to maturity, plant height (cm), number of productive tillers per plant, panicle length (cm), panicle diameter (cm), 1000-grain weight (g), grain yield per plant (g), stover yield per plant (g), harvest index (%), protein content (%) iron content and zinc content. (Nitrogen content was determined by the Kjeldahl method (1883) using a KEL PLUS distillation unit (Pelican Equipment, Chennai, India). The crude protein content of the sample was calculated as 6.25 times its nitrogen content and expressed as percentage.). The iron and zinc estimation were done by using Atomic Absorption Spectrophotometer by following the method proposed by Jackson (1973) and expressed as ppm. The combining ability analysis was performed to determine the general and specific combining ability effects as per (Kempthorne, 1957).

## RESULTS AND DISCUSSION

The result of analysis of variance (ANOVA) for combining ability for 13 characters in pearl millet is presented in **Table 1**. The mean squares due to male and female were found non-significant for most of the characters but mean due to female × male interaction were observed to be significant for all characters. The general combining ability (*gca*) variances of parents were significant for days to 50 % flowering, plant height, panicle length, 1000-grain weight and zinc content. Specific combining ability (*sca*) variances for female × male interaction were also highly significant for all the characters except iron content. The magnitude of *sca* variances was higher than *gca* variances for most of characters except panicle diameter and 1000-grain weight which indicates the preponderance of non-additive gene action. This was supported by low magnitude of $\sigma^2 gca/\sigma^2 sca$ ratios which further shows the importance of non-additive components in the inheritance of majority of the characters studied. Assessment of general combining ability (GCA) effects for parents and specific combining ability (SCA) effects for hybrids was done and the character-wise sorting of general combining ability effects of the parents has been presented in **Table 2**. In this investigation it was observed that none of the parents was good general combiner for all the characters. The GCA effects of the parents revealed that amongst male parents, RIB 17 S/109 was found be a good general combiner for grain yield per plant, 1000-grain weight, harvest index, plant height and panicle diameter. Male parent RIB 16300 was observed to be good general combiner for panicle length, 1000-grain weight, grain yield per plant and stover yield per plant and RIB 37-40 S/17 was found to be good general combiner for days to 50 % flowering, days to maturity and zinc content. The male parent RIB 13-16 S/17 was found to be good general combiner for panicle diameter, grain yield per plant and harvest index. Amongst the females, ICMA 96666 had good general combiner for 1000-grain weight, plant height, panicle length, protein content, iron content and zinc content, ICMA 97111 was found good general combiner for grain yield per plant and stover yield per plant and ICMA 94111 was found to be good general combiner for days to maturity, panicle diameter and harvest index. These results are in accordance with the findings of Pareek *et al.* (2008), Chaudhary *et al.* (2012), Kanatti *et al.* (2014), Khandagale *et al.* (2014), Bhardwaj *et al.* (2015), Badurkar *et al.* (2018) and Reshma *et al.* (2019). Most of the females and males were showing average GCA for most of the characters.

The character-wise sorting of specific combining ability effects of the hybrids is presented in **Table 3**. The positive specific combining ability is desirable for all the characters except days to maturity and days to 50 % flowering. Significant specific combining ability in desirable direction was observed by many crosses for the characters zinc content (8), grain yield per plant (6), protein content (4), panicle diameter (3), 1000-grain weight (3), stover yield per plant (3), harvest index (3), number of productive tillers per plant (3), panicle length (2), days to maturity (2), days to 50 % flowering (1), plant height (1) and iron content (1). These results are in conformity with the findings of Pareek *et al.* (2008),

**Table 1. ANOVA for combining ability of grain yield and its component characters in pearl millet**

| Source of variation | DF | Days to 50% Flowering | Days to Maturity | Plant Height (cm) | No. of Productive Tillers per Plant | Panicle Length (cm) | Panicle Diameter (cm) | 1000-grain weight (g) | Grain Yield per Plant (g) | Stover Yield per Plant(g) | Harvest Index (%) | Protein Content (%) | Iron Content (ppm) | Zinc Content (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replications | 2 | 11.033* | 0.308 | 360.732* | 0.477* | 8.339** | 0.100* | 2.226** | 57.148* | 239.801 | 2.808 | 2.900 | 640.853** | 2.362 |
| Female | 3 | 4.808 | 7.967 | 995.545** | 0.609 | 34.013** | 0.384** | 6.771** | 116.300 | 166.770 | 54.785 | 10.695 | 813.137* | 435.091* |
| Male | 9 | 35.797** | 8.793 | 224.661 | 0.484 | 17.274** | 0.374** | 12.931** | 141.822 | 342.699 | 45.943 | 2.521 | 116.283 | 264.586* |
| Female x Male | 27 | 6.271** | 4.207** | 184.822** | 0.289** | 5.336** | 0.063** | 1.409** | 114.815** | 279.008** | 41.157** | 4.455** | 202.189* | 116.569** |
| Error | 78 | 2.905 | 1.522 | 84.341 | 0.133 | 1.635 | 0.022 | 0.420 | 18.219 | 77.186 | 14.738 | 1.230 | 107.258 | 13.177 |
| $\sigma^2_{female}$ | | 0.063 | 0.215 | 30.373** | 0.016 | 1.079** | 0.012 | 0.212* | 3.269 | 2.986 | 1.335 | 0.315 | 23.529* | 14.064* |
| $\sigma^2_{male}$ | | 2.741** | 0.606 | 11.693 | 0.029 | 1.303* | 0.029 | 1.043** | 10.300 | 22.126 | 2.600 | 0.108 | 0.752 | 20.951* |
| $\sigma^2_{gca}$ | | 0.828** | 0.327 | 25.036* | 0.020 | 1.143** | 0.017 | 0.449* | 5.278 | 8.455 | 1.696 | 0.256 | 17.022 | 16.032* |
| $\sigma^2_{sca}$ | | 1.122** | 0.895** | 33.494** | 0.052** | 1.233** | 0.014** | 0.330** | 32.198** | 67.274** | 8.806** | 1.075** | 31.644* | 34.464** |
| $\sigma^2_{gca}/\sigma^2_{sca}$ | | 0.738 | 0.365 | 0.747 | 0.385 | 0.927 | 1.214 | 1.361 | 0.164 | 0.126 | 0.193 | 0.238 | 0.538 | 0.465 |

*, ** Significant at 5% and 1%; $\sigma^2f$, $\sigma^2m$, $\sigma^2gca$, $\sigma^2sca$ = Females, males, *gca* and *sca* variance, respectively. d.f. = degree of freedom

**Table 2. Estimates of general combining ability effect of parents for grain yield and its component characters in pearl millet**

| Parents | Days to 50% Flowering | Days to Maturity | Plant Height (cm) | No. of Productive Tillers per Plant | Panicle Length (cm) | Panicle Diameter (cm) | 1000-Grain Weight (g) | Grain Yield per Plant (g) | Stover Yield per Plant (g) | Harvest Index (%) | Protein Content (%) | Iron Content (ppm) | Zinc Content (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Female** | | | | | | | | | | | | | |
| ICMA 94111 | -0.06 | -0.72** | -3.44* | 0.13 | -0.23 | 0.11** | -0.71** | 1.45 | 0.003 | 1.52* | 0.32 | -0.15 | -2.21** |
| ICMA 96666 | -0.43 | 0.28 | 8.62** | 0.02 | 1.28** | 0.03 | 0.31* | -0.42 | -2.05 | 0.49 | 0.57** | 7.07** | 2.13** |
| ICMA 97111 | -0.06 | 0.45* | -2.76 | -0.20** | 0.23 | 0.02 | 0.19 | 1.58* | 3.30* | -0.32 | -0.79** | -5.37** | -4.09** |
| ICMA 97444 | 0.54 | -0.02 | -2.42 | 0.06 | -1.29** | -0.16** | 0.21 | -2.62** | -1.25 | -1.68* | -0.10 | -1.56 | 4.17** |
| $S.E._{(gi)}$ | 0.31 | 0.23 | 1.68 | 0.07 | 0.23 | 0.03 | 0.12 | 0.78 | 1.60 | 0.70 | 0.20 | 1.89 | 0.66 |
| **Male** | | | | | | | | | | | | | |
| RIB 3135-18 | -1.19* | -0.10 | -7.43** | 0.22* | -0.34 | 0.02 | 0.09 | 0.19 | 4.68 | -1.77 | 0.65* | 5.53 | -0.40 |
| RIB 494 | -1.86** | -0.10 | 4.93 | -0.12 | 2.28** | 0.13** | -0.31 | -2.96* | 0.13 | -2.49* | 0.23 | -1.44 | -2.71* |
| RIB 17 S/109 | 1.81** | -0.10 | 5.57* | -0.35** | -0.23 | 0.40** | 2.67** | 5.39** | 2.18 | 3.50** | -0.69* | -3.62 | 1.36 |
| RIB 16 S/111 | 0.23 | 0.15 | 2.44 | 0.32** | -0.08 | -0.12** | -0.35 | 0.42 | 4.89 | -1.82 | 0.31 | 0.51 | 2.80** |
| RIB 16300 | 2.06** | 1.15** | 0.66 | 0.02 | 1.49** | -0.14** | 0.49* | 2.79* | 5.44* | -0.47 | 0.43 | 0.68 | -1.12 |
| RIB 16296 | -0.69 | 0.48 | -0.08 | 0.13 | 0.56 | -0.16** | -0.29 | -2.29 | -3.19 | -1.22 | -0.48 | 2.47 | -1.36 |
| RIB 17-20 S/17 | 0.14 | 0.07 | -0.78 | -0.03 | -1.03** | 0.002 | -0.53** | -1.26 | -4.36 | 0.84 | -0.55 | -4.06 | -2.86** |
| RIB 33-36 S/17 | 1.14* | 0.23 | -3.64 | -0.15 | -1.88** | -0.06 | -1.04** | -6.63** | -11.76** | 0.55 | 0.01 | -3.18 | -4.96** |
| RIB 37-40 S/17 | -3.19** | -2.18** | -5.10 | 0.12 | -0.11 | -0.18** | -0.83** | 1.76 | 2.93 | 0.27 | 0.29 | 2.83 | 11.79** |
| RIB 13-16 S/17 | 1.56** | 0.40 | 3.42 | -0.15 | -0.66 | 0.11* | 0.10 | 2.59* | -0.94 | 2.60* | -0.21 | 0.29 | -2.53* |

*, ** Significant at 5% and 1%

Chaudhary *et al.* (2012), Kanatti *et al.* (2014), Khandagale *et al.* (2014), Bhardwaj *et al.* (2015), Badurkar *et al.* (2018), Reshma *et al.* (2019), Barathi *et al.* (2022) and Yadav *et al*. (2022).

Earliness is desirable in pearl millet hence negative GCA and SCA effects are considered. The results revealed that specific combining ability effects ranged from -2.91 (ICMA 96666 × RIB 37-40 S/17) to 3.13 (ICMA 97444 × RIB 37-40 S/17). Three hybrids showed significant SCA effects, but only hybrid ICMA 96666 × RIB 37-40 S/17 (-2.91) showed significant negative desirable SCA effect for days to 50% Flowering. For the trait early maturity, specific combining ability effects for crosses ranged from -2.62 (ICMA 96666 × RIB 37-40 S/17) to 1.63 (ICMA 94111 × RIB 33-36 S/17). A total of six hybrids showed significant SCA effects, out of which two hybrids, ICMA 94111 × RIB 3135-18 (-2.03) and ICMA 96666 × RIB 37-40 S/17 (-2.62) showed significant negative SCA effects and were found to be desirable for 50% days to flowering. For the trait plant height, two hybrids showed significant SCA effects and out of these hybrid ICMA 97111 × RIB 17 S/109 (14.98) recorded positive SCA effects.

Estimates of SCA effects for number of productive tillers per plant ranged from -0.38 (ICMA 94111 × RIB 17-20 S/17) to 0.75 (ICMA 96666 × RIB 3135-18). Three hybrids ICMA 96666 × RIB 3135-18 (0.75), ICMA 97444 × RIB 17-20 S/17 (0.56) and ICMA 94111 × RIB 37-40 S/17 (0.54) showed significant positive SCA effects. The study showed that a total of five hybrids showed significant SCA effects of which two hybrids, ICMA 96666 × RIB 16300 (2.25) and ICMA 97111 × RIB 16 S/111 (2.07) exhibited positive SCA effects for panicle length. For panicle diameter, six hybrids exhibited significant SCA effects, out of which three hybrid ICMA 94111 × RIB 16300 (0.23), ICMA 97111 × RIB 16300 (0.22) and ICMA 97444 × RIB 37-40 S/17 (0.20) showed positive SCA effects which is desirable (**Table 3**).

For 1000-grain weight, SCA effects ranged from -1.63 (ICMA 97444 × RIB 17 S/109 and ICMA 97444 × RIB 16300) to 2.01 (ICMA 96666 × RIB 17 S/109). Five hybrids showed significant SCA effects, out of which three crosses, ICMA 96666 × RIB 17 S/109 (2.01), ICMA 97444 × RIB 3135-18 (0.88) and ICMA 97444 × RIB 13-16 S/17 (0.77) recorded positive SCA effects. For grain yield per plant, six hybrids showed positive SCA effects. The best specific combiner was ICMA 96666 × RIB 16300 (13.02) followed by ICMA 97444 × RIB 17-20 S/17 (9.53) and ICMA 94111 × RIB 37-40 S/17 (9.18) which exhibited higher positive SCA effects for grain yield per plant (**Table 3**).

Amongst 40 hybrids evaluated, three hybrids *viz*., ICMA 94111 × RIB 37-40 S/17 (17.65), ICMA 94111 × RIB 494 (13.39) and ICMA 96666 × RIB 16300 (12.45) showed significant positive SCA effects for stover yield per plant. Thus, these crosses are considered to be the best specific combiners for stover yield per plant. For harvest index of the hybrids, the SCA effects varied from -4.98 (ICMA 97111 × RIB 3135-18) to 5.93 (ICMA 97444 × RIB 17-20 S/17). Three hybrids *viz*., ICMA 97444 × RIB 17-20 S/17 (5.93), ICMA 97444 × RIB 3135-18 (5.92) and ICMA 94111 × RIB 16296 (5.29) showed positive significant SCA effect.

For protein content, specific combining ability effects for crosses varied from -2.32 (ICMA 97111 × RIB 17 S/109) to 1.63 (ICMA 94111 × RIB 16 S/111). Four hybrids *viz*., ICMA 94111 × RIB 16 S/111 (1.63), ICMA 97444 × RIB 17 S/109 (1.59), ICMA 96666 × RIB 3135-18 (1.58) and ICMA 94111 × RIB 16296 (1.29) showed positive significant SCA effects. Estimates of SCA effects of crosses ranged from -25.08 (ICMA 97111 × RIB 17 S/109) to 19.88 (ICMA 96666 × RIB 17 S/109) for iron content. Two hybrids showed significant SCA effects of which only the hybrid ICMA 96666 × RIB 17 S/109 (19.88) attributed towards positive desirable direction for iron content. For zinc content specific combining ability effects of the crosses varied from -10.06 (ICMA 94111 × RIB 37-40 S/17) to 13.87 (ICMA 97444 × RIB 16300). A total of eight hybrids showed positive significant SCA effect. The best three specific combiner were ICMA 97444 × RIB 16300 (13.87) followed by ICMA 97444 × RIB 37-40 S/17 (11.76) and ICMA 96666 × RIB 13-16 S/17 (7.86) which exhibited high positive significant SCA effects for zinc content (**Table 3**).

The estimation of general combining ability suggested that parents, RIB 17 S/109, RIB 16300, RIB 37-40 S/17, RIB 13-16 S/17, ICMA 96666 and ICMA 94111 were good general combiners for yield and its contributing characters. Improvement of characters for developing high yielding varieties may be achieved through crossing between inbreds, RIB 3135-18, RIB 494 and RIB 37-40 S/17 for earliness and between RIB 17 S/109, RIB 16300, RIB 37-40 S/17, B × B crossing between the males of ICMA 94111 and ICMA 96666 for grain yield and yield contributing traits. The cross combinations could be exploited for obtaining desirable recombinants from the segregating population to develop potential restorer and B lines of pearl millet to be used in future breeding programmes. Parents RIB 17 S/109, RIB 16300, ICMA 94111 and ICMA 96666, RIB 37-40 S/17 and RIB 13-16 S/17 could be exploited for heterosis breeding for developing high yielding early maturing nutritionally rich hybrids to suit drought prone areas of the country. The best hybrid ICMA 94111 x RIB 16296 involved low x low performing parents which exhibited high positive significant sca effect for grain yield and other most of yield contributing and quality traits like protein content, iron and zinc content. These specific combiner lines may be exploited to develop iron and zinc rich hybrids along with grain yield.

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**Table 3. Estimates of specific combining ability for grain yield and its component characters in pearl millet**

| | Hybrids | Days to 50% Flowering | Days to Maturity | Plant Height (cm) | Number of Productive Tillers per Plant | Panicle Length (cm) | Panicle Diameter (cm) | 1000-Grain Weight (g) | Grain Yield per Plant (g) | Stover Yield per Plant (g) | Harvest Index (%) | Protein Content (%) | Iron Content (ppm) | Zinc Content (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ICMA 94111 x RIB 3135-18 | -0.61 | -2.03** | -1.48 | -0.23 | -0.27 | -0.07 | -0.57 | 4.42 | 2.10 | 1.82 | -1.14 | -2.89 | 5.22* |
| 2 | ICMA 94111 x RIB 494 | 0.39 | -0.70 | -6.64 | 0.08 | 0.37 | 0.03 | 0.13 | 1.03 | 13.39* | -4.67* | 0.65 | -0.99 | 0.07 |
| 3 | ICMA 94111 x RIB 17 S/109 | -0.61 | 0.30 | -5.81 | -0.13 | -1.38 | -0.01 | -0.11 | -4.12 | -13.20* | 3.21 | -0.10 | -4.20 | 0.40 |
| 4 | ICMA 94111 x RIB 16 S/111 | -0.36 | 1.05 | -5.81 | 0.27 | 0.00 | 0.01 | -0.13 | -3.28 | -7.91 | 0.99 | 1.63* | 2.06 | 3.83 |
| 5 | ICMA 94111 x RIB 16300 | 0.48 | -0.95 | 0.44 | -0.16 | 0.03 | 0.23** | 0.20 | -3.72 | 1.34 | -3.02 | 0.08 | -5.24 | -6.45** |
| 6 | ICMA 94111 x RIB 16296 | 0.56 | 0.38 | -0.69 | 0.39 | 1.03 | 0.08 | 0.32 | 8.63** | 4.37 | 5.29* | 1.29* | 1.91 | 7.58** |
| 7 | ICMA 94111 x RIB 17-20 S/17 | 1.39 | 0.13 | 0.87 | -0.38 | -0.18 | -0.14 | -0.12 | -8.87** | -8.33 | -4.50* | -2.31** | 4.93 | 1.19 |
| 8 | ICMA 94111 x RIB 33-36 S/17 | 1.06 | 1.63* | 2.61 | -0.26 | -1.07 | -0.12 | -0.04 | -1.03 | -6.80 | 2.63 | 0.33 | -2.88 | 0.62 |
| 9 | ICMA 94111 x RIB 37-40 S/17 | -1.94 | 0.05 | 7.20 | 0.54* | 1.23 | 0.03 | 0.12 | 9.18** | 17.65** | -0.89 | -0.34 | 8.45 | -10.06** |
| 10 | ICMA 94111 x RIB 13-16 S/17 | -0.36 | 0.13 | 9.31 | -0.13 | 0.25 | -0.05 | 0.19 | -2.25 | -2.61 | -0.86 | -0.11 | -1.15 | -2.41 |
| 11 | ICMA 96666 x RIB 3135-18 | 0.09 | 0.30 | -4.33 | 0.75** | -0.51 | 0.14 | -0.48 | -2.58 | 2.02 | -2.76 | 1.58* | -3.17 | -3.21 |
| 12 | ICMA 96666 x RIB 494 | 0.43 | 1.30 | -3.63 | -0.24 | -0.34 | -0.03 | -0.62 | 0.77 | -4.10 | 2.59 | -0.93 | -3.14 | 0.94 |
| 13 | ICMA 96666 x RIB 17 S/109 | 2.09* | 1.30 | -4.27 | -0.02 | -0.06 | 0.07 | 2.01** | -1.45 | 7.32 | -4.30 | 0.82 | 19.88** | 6.57** |
| 14 | ICMA 96666 x RIB 16 S/111 | 0.68 | 0.38 | -5.87 | -0.28 | -2.51** | -0.12 | -0.31 | -6.42* | -8.20 | -1.95 | -1.78** | -4.26 | -3.97 |
| 15 | ICMA 96666 x RIB 16300 | -1.49 | -0.95 | 6.12 | -0.18 | 2.25** | -0.13 | 0.48 | 13.02** | 12.45* | 4.38 | 0.47 | -5.26 | -6.95** |
| 16 | ICMA 96666 x RIB 16296 | 0.26 | 0.05 | 4.65 | 0.03 | 0.32 | -0.04 | -0.37 | 2.23 | 1.48 | 2.05 | 0.45 | 3.35 | -5.65** |
| 17 | ICMA 96666 x RIB 17-20 S/17 | 0.76 | 0.47 | 4.08 | -0.20 | 0.31 | 0.00 | 0.20 | -1.47 | -5.75 | 2.26 | 0.51 | -0.59 | 2.09 |
| 18 | ICMA 96666 x RIB 33-36 S/17 | -0.58 | -0.37 | 4.88 | 0.18 | 0.62 | 0.12 | -0.53 | 0.43 | 4.72 | -3.52 | 0.62 | -3.17 | 4.59* |
| 19 | ICMA 96666 x RIB 37-40 S/17 | -2.91** | -2.62** | -8.06 | -0.28 | -1.15 | -0.06 | -0.07 | -5.28* | -12.10* | 1.50 | -0.99 | -5.71 | -2.26 |
| 20 | ICMA 96666 x RIB 13-16 S/17 | 0.68 | 0.13 | 6.42 | 0.25 | 1.07 | 0.06 | -0.33 | 0.75 | 2.17 | -0.27 | -0.75 | 2.06 | 7.86** |
| 21 | ICMA 97111 x RIB 3135-18 | -0.28 | 1.47* | 6.78 | -0.23 | 1.27 | -0.11 | 0.17 | -4.85 | 3.60 | -4.98* | 0.78 | 2.34 | 1.61 |
| 22 | ICMA 97111 x RIB 494 | -1.94 | -0.87 | 7.75 | -0.02 | 0.97 | 0.05 | -0.06 | 0.37 | -1.99 | 1.44 | 0.60 | -1.36 | -4.18* |

contd.

**Table 3. Continued..**

| | Hybrids | Days to 50% Flowering | Days to Maturity | Plant Height (cm) | No. of Productive Tillers per Plant | Panicle Length (cm) | Panicle Diameter (cm) | 1000-Grain Weight (g) | Grain Yield per Plant (g) | Stover Yield per Plant (g) | Harvest Index (%) | Protein Content (%) | Iron Content (ppm) | Zinc Content (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | ICMA 97111 x RIB 17 S/109 | -0.61 | -1.20 | 14.98** | 0.20 | 0.89 | 0.08 | -0.27 | 5.62* | 5.90 | 1.02 | -2.32** | -25.08** | 0.45 |
| 24 | ICMA 97111 x RIB 16 S/111 | 0.98 | -1.12 | 8.18 | -0.06 | 2.07** | 0.17 | 0.48 | 6.12* | 6.18 | 2.40 | -0.05 | 7.35 | 0.05 |
| 25 | ICMA 97111 x RIB 16300 | 0.81 | 1.55* | 1.36 | 0.30 | 0.23 | 0.22* | 0.20 | 1.42 | 4.16 | -0.08 | 0.73 | 3.69 | -0.47 |
| 26 | ICMA 97111 x RIB 16296 | -0.44 | -0.45 | -10.31 | -0.15 | -1.37 | -0.19* | 0.02 | -10.77** | -13.20* | -4.17 | -0.49 | -1.57 | 4.97* |
| 27 | ICMA 97111 x RIB 17-20 S/17 | -1.61 | -0.70 | -6.01 | 0.02 | -0.81 | 0.02 | -0.15 | 0.80 | 9.96 | -3.69 | 0.71 | -1.98 | 0.67 |
| 28 | ICMA 97111 x RIB 33-36 S/17 | 0.06 | -1.20 | 0.19 | 0.14 | 0.20 | 0.04 | 0.63 | 3.23 | -1.97 | 3.73 | -0.68 | 9.28 | -3.13 |
| 29 | ICMA 97111 x RIB 37-40 S/17 | 1.73 | 1.55* | -7.78 | -0.20 | -1.37 | -0.18* | -0.38 | -2.95 | -9.19 | 1.85 | 0.84 | 5.04 | 0.56 |
| 30 | ICMA 97111 x RIB 13-16 S/17 | 1.31 | 0.97 | -15.13** | 0.00 | -2.08** | -0.09 | -0.64 | 1.02 | -3.45 | 2.48 | -0.12 | 2.30 | -0.53 |
| 31 | ICMA 97444 x RIB 3135-18 | 0.79 | 0.27 | -0.96 | -0.29 | -0.48 | 0.03 | 0.88* | 3.02 | -7.72 | 5.92** | -1.21 | 3.72 | -3.62 |
| 32 | ICMA 97444 x RIB 494 | 1.13 | 0.27 | 2.51 | 0.18 | -1.01 | -0.04 | 0.55 | -2.17 | -7.30 | 0.63 | -0.32 | 5.49 | 3.16 |
| 33 | ICMA 97444 x RIB 17 S/109 | -0.88 | -0.40 | -4.90 | -0.06 | 0.54 | -0.14 | -1.63** | -0.05 | -0.02 | 0.08 | 1.59* | 9.41 | -7.41** |
| 34 | ICMA 97444 x RIB 16 S/111 | -1.29 | -0.32 | 3.50 | 0.08 | 0.45 | -0.06 | -0.05 | 3.58 | 9.93 | -1.44 | 0.19 | -5.16 | 0.09 |
| 35 | ICMA 97444 x RIB 16300 | 0.21 | 0.35 | -7.91 | 0.04 | -2.51** | -0.31** | -0.89* | -10.72** | -17.95** | -1.28 | -1.29* | 6.81 | 13.87** |
| 36 | ICMA 97444 x RIB 16296 | -0.38 | 0.02 | 6.35 | -0.27 | 0.02 | 0.15 | 0.03 | -0.10 | 7.35 | -3.18 | -1.25 | -3.69 | -6.90** |
| 37 | ICMA 97444 x RIB 17-20 S/17 | -0.54 | 0.10 | 1.05 | 0.56** | 0.68 | 0.13 | 0.06 | 9.53** | 4.12 | 5.93** | 1.09 | -2.36 | -3.95 |
| 38 | ICMA 97444 x RIB 33-36 S/17 | -0.54 | -0.07 | -7.68 | -0.06 | 0.25 | -0.05 | -0.06 | -2.63 | 4.05 | -2.84 | -0.27 | -3.24 | -2.09 |
| 39 | ICMA 97444 x RIB 37-40 S/17 | 3.13** | 1.02 | 8.64 | -0.06 | 1.29 | 0.20* | 0.33 | -0.95 | 3.63 | -2.46 | 0.49 | -7.78 | 11.76** |
| 40 | ICMA 97444 x RIB 13-16 S/17 | -1.63 | -1.23 | -0.61 | -0.12 | 0.77 | 0.08 | 0.77* | 0.48 | 3.90 | -1.36 | 0.99 | -3.21 | -4.92* |
| | SE ($S_{ij}$) | 0.98 | 0.71 | 5.30 | 0.21 | 0.74 | 0.08 | 5.07 | 2.46 | 0.37 | 2.22 | 0.64 | 5.98 | 2.10 |

*, ** Significant at 5% and 1%; SE ($S_{ij}$) = Standard error of hybrids

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