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Heterotic evaluation for phonological and quality traits in CMS based rice (*Oryza sativa* L.) hybrids

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Abstract

Heterosis for yield, yield components and quality traits of 54 hybrids developed by using three CMS lines and eighteen allocytoplasmic restorers developed by recombination breeding were crossed in LxT design and evaluated in RBD. The magnitude and direction of heterosis over better parent and standard check differed from character to character depending upon cross combinations. High amount of heterosis was observed for grain yield/plant, filled seeds / panicle, test weight, days to 50% flowering, panicle length, flag leaf length, head rice recovery, length/breadth ratio, kernel breadth after cooking and volume expansion ratio. The manifestation of heterosis for grain yield/plant is evident by significant superiority of hybrid over better parent ranged from -57.45** to 71.28** and over standard check ranging from -27.53** to 149.44**. For grain yield/plant the hybrids, 68897A x RR23(149.44**), 68897A × WGL 676(95.51**), 79156A × WGL 676(95.51**) 68897A ×WGL 1063(90.45**) 79128A × R17(83.15**) recorded significant relative heterosis, heterobeltiosis and standard heterosis, while 79156A × RR15 and 68897A x RR15 recorded for head rice recovery. The hybrids *viz*., 79156A x RR3, 79156A x RR15, 79156A x WGL347, 79128A x RR15, 68897A x RR3, 68897A x RR17, 68897A x RR50, 68897A x RR55 and 68897A x MTU11-320-11 performed well for grain yield/plant combined with several other important yield components and quality traits *viz*, head rice recovery, kernel length, length/breadth ratio and kernel elongation ratio in desired direction. Thus these hybrids need to be further tested in observational/multilocation trials before the commercial exploitation of their heterotic potential.

Keywords: Rice hybrids, heterosis, yield, quality traits

Introduction

Rice is the staple food for more than half of the world population and 90% of the population of Asian countries and rice plays an important role in providing food security, alleviating malnutrition and poverty in Asia and the world. It is predicted that the world's population will continue to increase. So that rice production needs to be increased every year to feed the increasing population. Therefore enhancing productivity through novel genetic approaches like hybrid rice was felt necessary. Exploitation of heterosis is considered to be one of the outstanding achievements of plant breeding. Hybrid rice technology is practically, feasible technology to increase the future rice production. Hybrid rice can yield about 15-20% more than even the best of the improved or high yielding varieties (Yuan 1994) [1]. Heterosis phenomenon in rice was first observed by Jones (1926) [2] who found that some F_1 hybrids had more culms and higher yield than their parents. Heterosis is the important phenomenon that exhibits superior phenotypes comparative to its parents including dwarfness, earliness, superior biomass production, better grain yield, good grain quality etc. World wide at present the CGMS (three line system) and EGMS system are mostly used for developing rice hybrids. After china, India is the first country to adopt the hybrid rice technology on a commercial scale. Ample number of male sterile lines, their maintainer and restorer lines in rice have been developed to generate good rice hybrids. Further it is important to identify promising restorers and cross combinations based on perse performance, combining ability effects and heterosis still remain best option for increasing breeding efficiency for ultimate use in the development of experimental hybrids (Yuang and Virmani 1991) [3]. The increased yield of rice hybrids alone does not guarantee profitability to farmers if their grain quality is not acceptable and they get a low price in the market (Khush *et al.* 1988 [4]: Tiwari *et al.*, 2011) [5]. Therefore special attention should be given to quality traits in addition to grain yield and human demand for high quality rice is continuously on an increase. Thus the most important challenge in hybrid rice breeding is to ensure that the heterotic rice hybrids possess grain quality that is at least comparable if not superior to that of popular inbred varieties grown by the farmers.

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The direction (positive or negative) and magnitude of heterosis in desired direction is of paramount importance in deciding the practical and economical feasibility of the heterosis breeding programme. It is imperative that along with the yield and yield attributes, higher magnitude of heterosis for quality traits be taken into consideration during the commercial development of rice hybrids. Hence, the present study was undertaken to assess the extent of heterosis and to identify best cross combinations on the basis of grain yield and quality traits for further utilization and commercialization.

Materials and Methods

The present study was conducted at Regional Agricultural Research Station, Warangal, PJTSAU, Telangana, India. The experimental material comprised of three cytoplasmic male sterile lines (79156A, 79128A and 68897A) and 18 restorers (RR3,RR15, RR17, RR23, RR32, RR50, RR55, RR65, WGL347, WGL616, WGL674, WGL676, WGL705, WGL739,WGL810, WGL1063, MTU1156 and MTU11320-20) which were crossed in L x T design during *rabi* 2016-17, staggered sowing of each parent was done to facilitate effective crossing. Each CMS line was crossed with each restorer resulted in development of 54 F_1 hybrids. First eight restorers were developed by allocytoplasmic restorer line improvement programme by making (R_1 x R_2), R_3 x (R_1 x R_2), (R_1 x R_2//R_3 x R_4) single, double and three way crosses among selected restorer lines and selections carried out by following pedigree method of breeding and rest of the lines were advanced breeding lines. The 54 F_1 hybrids along with female parents (isogenic maintainer lines of three CMS lines), 18 restorers and standard check PA6444 were raised during *Kharif*2017 in two replications. Each entry was planted in 2 rows of 4 m length by adjusting spacing of 20 x15 cm between the rows and plants with single seedling per hill.

Twenty five days old seedlings were transplanted single plant per hill in two rows of 1.2 mts length. The performance of F_1 hybrid combination and their parents were evaluated by recording observations on ten randomly selected plants from each plot excluding the border plants on the following attributes as per the standard evaluation system i,e plant height (cm), panicle length (cm), effective tillers/plant, flag leaf length (cm), flag leaf width (cm), filled seeds/panicle, unfilled seeds/panicle, self fertility (%), Test weight (g), grain yield/plant except days to 50% flowering which was computed on plot wise basis. Due to male sterility nature of the CMS lines or female lines their corresponding maintainer lines were used for studying yield and quality traits.

Data was also recorded on physical and chemical quality characters *viz*., hulling percent (%), milling percent (%), head rice recovery (%), kernel length (mm), kernel width (mm), length/breadth ratio, kernel length after cooking (mm), kernel width after cooking (mm), kernel elongation ratio, alkali spreading value, volume expansion ratio and water uptake (ml), Observations on hulling and milling was taken with the help of Satake company make laboratory huller(Type THU35A) and polisher(TypeTMO5). Data on head rice recovery was recorded. Kernel length and kernel width of 20 whole milled rice were measured by means of dial calliper and length and breadth ratio was computed as per Murthy and Govindaswamy (1967) [6]. Kernel elongation ratio was determined by soaking 5g of whole milled rice in 12 ml distilled water for 10 minutes and later cooked for 15 minutes in water bath. Observations on the length and breadth of cooked kernels and elongation ratio were recorded with the help of graph sheet to quantify cooking traits, while water uptake, volume expansion ratio and alkali spreading value by following the standard procedures.

Heterosis for each trait was worked out by overall mean of each hybrid over replication for each trait. The mean data of isogenic maintainer lines (of respective CMS lines) were used as values for female parents. The mean data of each trait over plants was used for statistical analysis to measure relative heterosis (mid parent), heterobeltiosis (better parent) and standard heterosis (best check) were estimated as suggested by Hays *et al.* (1955) [7] and Liang *et al.* (1971) [8]. All statistical analysis was processed by windostat version 9.1 software. Significance of above three types of heterosis was tested by “t” value and it was evaluated by estimates of critical difference (C.D) for various traits at 0.05 and 0.01 levels of significance.

Results and Discussion

The analysis of variance showed significant variation due to genotypes for all the yield and quality traits studied (Table-1). The parents also exhibited significant differences for the characters under study. The lines and testers differed significantly for most of the traits. The parents Vs hybrids comparison was found to be significant for all the yield and quality traits except effective tillers, panicle density, filled seeds/panicle, hulling percent, kernel width, kernel elongation ratio and alkali spreading value indicating substantial amount of heterosis in hybrids. Similar results were recorded by Pandya and Tripathi (2006) [9], Singh *et al.* (2007) [10], Pratap *et al.* (2013) [11] and Kumar and Adilakshmi (2016) [12] and Thorat *et al.* (2017) [13]

Investigation on heterosis provides fundamental information regarding the utility of the cross combination and its use for commercial exploitation of magnitude of heterosis for yield, yield compounds and quality traits depends to a large extent on genetic variation, genetic base and adaptability of parents (Sahu *et al.* 2017) [14], Kumar and Adilaxmi 2016) [12]. The presence of significant amount of non additive gene action is a prerequisite for the commercial exploitation of heterosis in rice. The estimates of relative heterosis, heterobeltiosis and standard heterosis for yield, yield attributes and quality traits were showed that considerable amount of heterosis existed both in positive and negative direction for all the traits studied. (Table-2 and 3). Negative estimates of heterosis and heterobeltiosis are desirable for the trait days to 50% flowering to develop hybrids with early duration and dwarfnes. Hence these hybrids can be used to develop early maturing hybrids. For this character45 hybrids over midparent48 hybrids over better parent and 53 hybrids over standard check recorded significant negative heterosis in desirable direction. Whereas hybrid 79156A x RR15 has recorded significant positive heterobeltiosis (9.88^{**}) and can be utilized for developing late maturing hybrids. 79128A × RR3 recorded significant negative heterosis for days to 50% flowering and plant height in desired direction.

Semi dwarf plant height(80-100 cm) is desirable for recording higher yield in rice, as vigour in plant height may lead to unfavorable grain/straw ratio and below optimum yield due to lodging. Tall plants require more energy to translocation source to the sink (grain) and there by lower grain weight (Sen *et al.* 2011) [15]. On the other hand very dwarf plants (less than 70cm) are related with low dry matter and low grain production. The tendency of the hybridsbeing taller than the parents are very obvious. For plant height, negative value of heterosis is desirable, among 54 hybrids,18 hybrids over midparent, 44 hybrids over better parent and 18 over standard check were significantly better and the range was -23.16** (79128A x RR3) to 10.08 (79156A x WGL739) for mid parental heterosis, -30.98** (79128A x RR3) to 17.47** (79156A x MTU11-320-20) for hetrobeltiosis and -18.13** (79128A x RR3) to 14.22** (79128A x WGL1063) over standard check. For plant height, 79128A x RR3 and 68897A x RR55 recorded significant negative heterosis over mid parent, better parent and check and these hybrids can be used for developing semi dwarf hybrids, so that there will be no lodging. In the present investigation, plant height of F_1hybrids was almost equal or to some extent morethan the parents as observed by Virmani *et al.* (1982) [16]. Therefore in order to develop rice hybrids possessing semi dwarf plant type, both the parents of the hybrids should be semi dwarf possessing semi dwarfing genes. The study thus suggested that parents with semi dwarf desirable plant height (80-100 cm) should be choosen, so that the hybrid derived from these do not become taller than 100cm even after manifestation of heterosis for plant height under irrigated ecosystem. The hybrid 68897A x RR17 recorded significant negative heterosis for both days to 50% flowering and plant height for all the three types of heterosis so this hybrid can be used for developing short duration with semi dwarf and dwarf hybrids. Similar type of results was depicted by Rukminidevi *et al.* (2014) [17] and Sahu *et al.* (2017) [14]. Panicle length is the important component of grain yield as it bears the sink in rice. More is the length of the panicle, it likely to give more no. of grains per panicle. For the character panicle length, relative heterosis ranged from -11.82** (79128A x RR3) to 22.37** (79156A x WGL1063), hetrobeltiosis from -16.10** (79128A x RR23) to 17.43** (79156A x WGL-1063) and standard heterosis from -2.28 (79128A x MTU11-320-20) to 25.10** (79156A x RR32). Panicle length is the important component of grain yield, as it bears the sink in rice. More is the length of the panicle, it is likely to give more number of grains per panicle, resulting in higher productivity. The hybrid 79156A x RR23 recorded significant positive heterosis for panicle length and flag leaf length over mid parent, better parent and standard check. Together high panicle length and flag leaf length will results in high productivity due to more number of spikelets per panicle and photosynthetic efficiency due to more flag leaf length in hybrid rice.

Important character like effective tillers, significant positive relative heterosis ranged from -29.03** (79128A x RR3) to 48.15** (68897A x RR55), hetrobeltiosis from -31.25** to 42.86** and RR3) and standard heterosis from -8.33** to 83.35**. For this trait, the hybrids 68897A x RR55, 68897A x RR23 and 68897A x RR32 recorded significant heterosis for all the three types of heterosis and 68897A x RR23 showed highly significant standard heterosis indicating that these hybrids will have potential to give high production and productivity due to recording higher effective tillers. In rice, to increase the yield potential of hybrids/varieties number of filled grains/panicle is very important character, which has direct effect on yield for which high degree of heterosis was revealed, out of 54 hybrids the estimates of relative heterosis, heterobeltiosis and standard heterosis were significant and positive, 26 hybrids have shown over mid parent, 12 hybrids over better parent and 16 over standard check. The range of relative heterosis for filled seeds/panicle ranged from -33.5** to 92.29**, heterobeltiosis from -48.71** to 76.2**. The hybrids 68897AxRR23 and 79156AxWGL347 recorded lowest and highest relative heterosis and heterobeltiosis respectively, while for standard heterosis the range was -46.02** (79156A x WGL810) to 64.49** (79128A x WGL1063).The hybrid 68897A x RR15 showed significant relative heterosis, heterobeltiosis and standard heterosis for filled grains/panicle, while 79156AxWGL347 showed significant positive heterobeltiosis and standard heterosis. The hybrid 79128A x RR15 (10.66**) followed by 79156A x MTU11-320 (8.03**) recorded significant standard heterosis, while 79156A x WGL616 (8.26*) showed significant positive hetrobeltiosis. Similar findings for effective tillers per plant, panicle length, filled seeds/panicle, test weight, days to 50% flowering and plant height were also reported by Singh and Singh (1979) [18], Pratap*et al.* (2013) [11], Shinde and Patel (2014) [19] and Dhanraj *et al.* (2019) [20].

Negative significant mid parent, better parent and standard heterosis were recorded by 68897A x RR3, 79128A x RR3 and 68897A x RR17 respectively in desired direction for unfilled seeds/panicle. It has direct effect on yield/plant. Hybrids with less number of unfilled seeds and more number of filled seeds per panicle are preferable. In general high pollen fertility (>85%) and spikelet fertility (>75%) should be desirable. Among the 54 hybrids seven hybrids for relative heterosis, one hybrid for heterobeltiosis and two hybrids for standard heterosis recorded significant positive heterosis.

Heterosis for seed yield in positive direction is desirable as higher grain yield is the main objective for almost all the breeding programmers. Virmani *et al.* (1981) [21] suggested that the yield advantage of 20% to 30% over best available standard variety should be sufficient to encourage farmer for adapting hybrids on large scale. In the present study, out of 54 hybrids, 32 hybrids have shown significant positive heterosis over mid parent, 12 hybrids over better parent and 35 hybrids over standard check. Relative heterosis ranged from -44.64* (79156A x RR32) to 115.33** (79156A x RR15), hetrobeltiosis from -57.45** (79156A x RR32) to 71.28** (68897A x RR32) and standard heterosis from -27.53* (79128A x RR55) to 149.44** (68897A x RR23). Eleven hybrids have shown all three types of heterosis i.e. relative heterosis, heterobeltiosis and standard heterosis for the important character grain yield/plant. It was noted that higher heterosis over better parent was found in some lower yielding crosses compared to other crosses which displayed high yield. This suggested that while selecting best hybids, besides heterotic performance over parent, the mean performance of the crosses should also be given due consideration. In this context the most desirable crosses showing high mean performance and high significant one or both types of heterosis for grain yield/plant are 68897A x RR23 (149.44**), 68897A × WGL 676 (95.51**), 79156A × WGL 676 (95.51**) 68897A ×WGL 1063 (90.45**) 79128A × R17 (83.15**) and these hybrids found significant for important yield components and quality traits indesired direction(Table-4). High magnitude of standard heterosis for grain yield in rice as observed in the present study have also been reported by, Kumar *et al.* (2010) [22], Rahsmi *et al.* (2014) [23], Rukmini Devi *et al.* (2017) [24], Sahu *et al.* (2017) [14], Thorat *et al.* (2017) [13] and Bano and Singh (2018) [25]. However a wide range of heterosis between negative and positive values for grain yield has been reported by Vaithiyalingam and Nandarajan (2010) [26], Singh *et al.* (2019) [27] and Akhileshkumar *et al.* (2020) [28].

For 1000 seed weight positive heterosis is desirable. In the present study, the magnitude of heterosis revealed that 31 hybrids showed the significant positive heterosis over mid parent, 17 over better parent and 25 hybrids over standard check. The hybrids 79128A x MTU1156 and 79128A x WGL810 were best for the traits and recorded significant positive heterosis for three types of heterosis average heterosis, hetrobeltiosis and standard heterosis in which 79128A x MTU1156 showed highly significant standard heterosis. Gokula Krishnan and Kumar *et al.* (2013) [29] and Sharma *et al.* (2013) [30] also reported highly significant positive heterosis for test weight.

Rice is marketed according to three grain size and shape classes (long, medium and short).Kernel dimensions are primary quality parameters in most of the processing, drying, handling equipment, breeding and grading. A quality grain is that which meets the end user specifications with respect to range of predetermined quality and safety standards. Present experimental results showed that the estimates of heterosis values for quality traits were low as compared to yield and yield contributing components. It is in confirmation with experimental finding of Veni *et al.* (2005) [31] and Roy *et al.* (2009) [32].

For hulling recovery, none of the hybrids showed significant positive heterosis for heterobeltiosis and standard heterosis, whereas three hybrids 79128A x R55 (4.08*) 68897A x RR65 (9.75**) and 79156A x WGL676 (9.47**) recorded significant positive average heterosis. Milling recovery is also very important quality trait in rice and for this trait, 6 hybrids recorded positive significant heterosis over mid parent and two hybrids each for heterobeltiosis and standard heterosis. The hybrid 79156A x RR15 and 68897 A x WGL616 recorded significant heterosis over mid parent, better parent and standard heterosis. Head rice recovery in an important character from miller and consumer point of view. A total of 15 hybrids for mid parent, 4 hybrids over better parent and 14 hybrids for standard check have shown significant positive heterosis. Relative heterosis for this character ranged from -58.36** (79156A x RR23) to 97.91** (68897A x RR15), while 57.9** (79156A x RR17) to 63.45** (79128A x MTU1156) for hetrobeltiosis and -58.79** (79128A x RR32) to 57.91** (791156A x RR17 for standard heterosis respectively. Two hybrids 79156A x RR15 and 68897A x RR15 have recorded positive significant heterosis over mid parent, better parent and standard heterosis.

Kernel length is one of the important grain quality parameters and its higher value is perceived to be desirable. Higher as well as lower values of kernel length over better parents and standard check for different cross combinations were observed in the present study. The hybrids 68897A x WGL674(10.06**, 8.07**, 3.09**), 68897A x WGL705 (7.99**, 7.55**, 13.47**), 68897A x WGL739 (14.79**, 14.77**, 20.78**) and 68897A x RR55 recorded significant magnitude of positive relative heterosis, heterobeltiosis and standard heterosis for kernel length. Estimates of negative significant heterosis for all three types of heterosis were exhibited by 79128A x RR32 and 68897A x RR65.Vivekanandan and Giridharan (1996) [33], Bano and Singh (2018) [25] and Rukmini Devi *et al.* *(*2017) [24] also reported negative as well as positive heterobeltiosis for kernel length. However Rahsmi *et al.* (2010) [23] reported positive estimates of standard heterosis for kernel length. In contrast Sarawgi *et al.* (2000) [34] reported the estimates of standard heterosis in negative direction only. For kernel breadth, negative heterosis is useful, for this trait 3 hybrids over mid parent, 10 hybrids over better parents and 39 hybrids over standard check exhibited significant negative heterosis. The hybrid 68897A x WGL676 (-17.04**) followed by 79156A x RR3, 79128A x WGL676, (-15.31**) and 79128A x WGL616 (-14.3**) respectively have shown significant negative standard heterosis.

Kernal length/breadth ratio before cooking is one of the important physical traits determining the quality of the grain. A higher value of kernel length/breadth ratio before cooking is desirable as the slender grain having length/breadth ratio of 3.0and above will fetch high premium price in the market and present study revealed both positive and negative values depending upon the cross combinations. Out of 54 hybrids only one hybrid 68897A x WGL676 exhibited positive significant heterosis over mid parent (21.86**), better parent (16.72**) and standard heterosis(38.72**). In remaining hybrids, 43 hybrids have shown significant positive standard heterosis, 7 hybrids have shown positive heterosis over better parent and six hybrids over mid parent. The highest heterobeltiosis and standard heterosis for length/breadth ratio was exhibited by the hybrids 68897Ax WGL676 and 68897AxWGL739 respectively. Both high and low value for kernel length/breadth ratio over the standard check has been reported by Sanghera and Hussain *et al.* (2012) [35]. Kernel length after cooking is one of the important grain quality parameter and its higher value perceived to be desirable. Present experimental results showed that higher as well as lower values of kernel length after cooking over their mid parent, better parent and standard check for different cross combination were observed in the present study. Significant positive value of heterobeltiosis was observed by cross 79156A x WGL676 (11.59**, 9.74**, 14.34**) showed significant positive herterosis over mid parent, better parent and standard check. Five hybrids showed significant positive standard heterosis. A range of value from low to high for kernel length after cooking has been observed by Kumar *et al.* (2010) [22], Srivastava and Jaiswal (2013) [36] and Waza *et al.* (2016) [37].

Lower values of kernel breadth after cooking and thus its heterosis in negative direction is desirable. Both lower and higher estimates of heterosis over their mid parent, better parents and standard check were observed in different cross combinations. Eighteen hybrids recorded significant negative heterosis over mid parent, better parent and standard check, whereas most of the crosses revealed non significant positive and negative heterosis. A range of values from low to high for kernel breadth after cooking has been observed by Kumar *et al.* (2010) [22], Srivastava and Jaiswal (2013) [36] and Bano and Singh (2018) [25].

Elongation ratio is an important measure of kernel expansion upon cooking that involves both lengthwise and breadth wise components. Linear elongation without breadth wise expansion is considered a highly desirable trait in the rice quality. During cooking rice grain absorb water and increase in length, breadth and volume. This increase may be accompanied by length wise or width wise splitting grain which is a non desirable character. Higher value of elongation ratio is considered to be desirable. All the hybrids in present study showed low and high values of kernel elongation ratio, only two hybrids over mid parent (68897A x RR65(14.71**), 79156A x RR55(10.29**)), each one hybrid over (79156A x RR55) better parent and standard check (79156A x RR3) exhibited significant positive heterosis. Sarawgi *et al.* (2000) [34] reported both positive and negative values for kernel elongation ratio.

Generally the most preferred grain type should possess the intermediate gelatinization temperature and in the present study alkali spreading value varied from intermediate to high and gelatinization temperature from low to intermediate for hybrids as well as check varieties. Tomar and Nanda (1985) [38] and Waza *et al.* (2016) [37] also recorded intermediate alkali digestion value and gelatinization temperature. Volume expansion ratio is the ability of the rice grain to expand upon cooking for which high values and positive heterosis was desirable. Twenty four hybrids showed significant positive heterosis over mid parent and nineteen hybrids over better parent and eighteen hybrids over standard check for the character volume expansion ratio. Among the hybrids 68897A x WGL739, 68897A x WGL810, 68897A x WGL347, 68897A x WGL674, 68897A x WGL1063 and 79128A x RR18 recorded higher significant positive heterosis for this character.

For the trait water uptake, twenty seven hybrids and one hybrid each recorded significant positive heterosis over mid parent, better parent and standard check, 68897A x WGL810(29.45**) recorded significant positive standard heterosis while 79156A x RR3 (49.36**, 16.78**) showed significant positive hetrobeltiosis and relative heterosis.

Table 1: Analysis of variance of combining ability for yield, yield components and quality traits in rice

Source of variation	D.F	Days to 50% flowering	Effective tillers/m2	Plant height	Panicle length	Flag leaf length	Flag leaf width	Panicle density	Filled seeds /panicle	Unfilled seeds/panicle	Self fertility	Test weight	Yield/plant
Replications	1	1.706	0.026	19.44	2.574	0.201	0.053	0.009	34.56	29.92	4.678	2.2	1.38
Treatments	74	85.607**	1.860**	142.723**	8.333**	49.102**	0.209**	4.244**	3814.159**	744.507**	98.357**	15.176**	86.321**
Parents	20	122.407**	1.545**	194.113**	7.861**	43.718**	0.271**	5.974**	3033.373**	380.930**	65.981**	27.828**	96.264**
Parent(line)	2	1.166	0.166	6.019	0.735	5.226	0.131*	4.329**	1138.166	42	34.277*	15.581**	5.54
Parent(tester)	17	111.915**	1.776**	118.737**	8.395**	42.123**	0.237**	4.305**	2298.816**	443.066**	64.282**	29.412**	56.210**
Parent (line x tester)	1	543.253**	0.321	1851.689**	13.028**	147.813**	1.133**	37.630**	19311.253**	2.48	158.285**	25.396**	958.620**
Parents vs. Crosses	1	1290.150**	0.038	1141.146**	97.884**	253.692**	2.680**	0.645	1530.88	802.287**	136.904**	68.19**	26.156*
Crosses	53	48.993**	2.014**	104.492**	6.821**	47.274**	0.139**	3.659**	4151.875**	880.616**	109.847**	9.402**	83.705**
Error	74	2.139	0.391	11.517	1.161	5.927	0.039	0.228	418.411	74.26	10.81	0.742	5.786
Total	149	43.59	1.118	76.733	4.732	27.331	0.123	2.221	2102.313	406.8	54.25	7.921	45.75

Table 2: Extent of Heterosis (H1), Heterobeltiosis (H2) and Standard heterosis (H3) in 54 hybrids for yield, yield components and quality traits in rice

Source of Variation	DF	Hulling recovery	Milling recovery	Head rice recovery	Kernel length	Kernel width	L/ B ratio	Kernel length after cooking	Kernel breadth after cooking	Kernel elongation ratio	Alkali spreading value	Volume expansion ratio	Water uptake
Replications	1	1.622	11.206	12.557	2E-05	0.02	0.06	0.026	0.00015	0.001	0.106	0.015	11.2
Treatments	74	7.179**	64.713**	255.455**	0.350**	0.035**	0.160**	0.543**	0.098**	0.011**	1.124**	2.255**	10256.976**
Parents	20	7.021**	87.220**	270.441**	0.428**	0.090**	0.269**	0.781**	0.1215**	0.008**	1.078**	0.275**	11770.773**
Parent(line)	2	5.431	39.781**	111.671**	0.131*	0.024*	0.283**	0.673**	0.140**	0.004	0.166	0.186	1754.166**
Parent(tester)	17	7.619**	95.508**	270.465**	0.426**	0.093**	0.181**	0.736**	0.12159**	0.009**	0.797*	0.267**	8616.013**
Parent (line x tester)	1	0.04	41.204*	587.583**	1.046**	0.178**	1.746**	1.778**	0.082*	0.00009	7.682**	0.600**	85434.920**
Parents vs. Crosses	1	6.762	109.516**	1610.613**	2.735**	0.00013	0.566**	1.599**	1.732**	0.013	0.251	24.609**	143140.326**
Crosses	53	7.246**	55.374**	224.231**	0.276**	0.014**	0.111**	0.433**	0.059**	0.012**	1.158**	2.581**	7178.499**
Error	74	2.018	6.346	3.589	0.032	0.005	0.028	0.096	0.018	0.003	0.417	0.076	267.3
Total	149	4.578	35.36	128.7	0.19	0.02	0.094	0.318	0.058	0.007	0.766	1.158	5226.9

Hybrid	Days to 50% flowering			Plant height(cm)			Panicle length(cm)			Effective tillers		
	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H3
79156AxRR3	-4.35**	-4.62**	-17.09**	2.17	-9.40**	7.46*	11.63**	8.47*	9.51*	-9.68	-12.5	16.67
79156AxRR15	10.20**	9.88**	-5.03**	3.88	-7.51**	8.69**	17.00**	10.46**	18.44**	-6.67	-6.67	16.67
79156AxRR17	-5.95**	-8.29**	-16.58**	-1.19	-11.39**	2.46	8.64*	3.62	8.75*	-3.23	-6.25	25.00*
79156AxRR23	-5.24**	-13.81**	-9.05**	3.72	-6.33*	6.58*	19.42**	15.73**	17.49**	-11.76	-21.05**	25.00*
79156AxRR32	-8.55**	-9.88**	-22.11**	1.65	0.09	-5.27	6.61	2.99	-1.9	-16.13*	-18.75*	8.33
79156AxRR50	-4.11**	-9.33**	-12.06**	-0.30	-9.83**	2.28	14.53**	1.54	25.10**	-7.14	13.33	8.33
79156AxRR55	0.83	-4.19**	-8.04**	-7.51**	-15.34**	-6.50*	3.87	-3.59	7.22	7.14	10.00	25.00*
79156AxRR65	-1.59	-9.71**	-6.53**	4.50	-4.66	6.06*	5.64	-4.22	12.17**	-3.45	-6.67	16.67
79156AxWGL347	-6.28**	-14.76**	-10.05**	4.88	-1.51	2.90	13.06**	10.48*	10.27*	0.00	0.00	25.00*
79156AxWGL616	-4.26**	-11.76**	-9.55**	4.67	-2.94	4.21	19.77**	16.38**	17.49**	14.29	-6.67	33.33**
79156AxWGL674	-4.07**	-10.15**	-11.06**	0.44	-7.77**	1.14	9.44	4.74	9.13*	-6.25	-11.76	25.00*
79156AxWGL676	-3.70**	-11.65**	-8.54**	-0.64	-10.05**	1.80	16.19**	14.29**	12.55**	-11.76	-21.05**	25.00*
79156AxWGL705	-5.04**	-12.68**	10.05**	1.63	-3.45	-1.58	16.26**	14.79**	12.17**	-10.34	-13.33	8.33

79156AxWGL739	4.40**	3.49*	-10.55**	10.08**	6.03	5.00	12.08**	11.20*	7.60	-9.68	-12.5	16.67
79156AxWGL810	-6.67**	-13.79**	-12.06**	2.66	-5.62*	3.25	14.57**	12.26**	11.41 **	3.45	0.00	25.00*
79156AxWGL1063	2.21	-2.63	-7.04**	5.42*	-6.58*	10.97**	22.37**	17.43**	21.67**	-10.34	-13.33	8.33
79156AxMTU1156	7.16**	5.65**	-6.03**	0.00	-7.42**	-0.26	5.84	3.23	3.42	-9.68	6.25	41.67**
79156AxMTU11-320-20	-6.37**	-10.58**	-15.08**	-7.82**	-17.47**	-4.21	2.4 7	-2. 35	2.66	0.00	-6.67	16.67
79128AxRR3	-1 2.87**	-13.87**	-25.13**	-23.16**	-30.98**	-18.3**	-11.82 **	13.56**	-12.74**	-29.03**	-31.25**	-8.33
79128AxRR15	8.24**	7.60**	-7.54**	1.97	-8.03**	8.08**	16.57**	10.99**	19.01**	-13.33	-13.33	8.33
79128AxRR17	-0.57	-2.76	-11.56**	1.04	-8.20**	6.15*	2.82	-1.09	3.80	-9.68	-12.5	16.67
79128AxRR23	-2.90*	-12.38**	-7.54**	8.01**	-1.16	12.47**	18.77 **	-16.10**	17.87**	11.76	0.00	58.33**
79128AxRR32	-8.93**	-9.47**	-23.12**	2.69	2.60	-2.90	2.35	-1.96	-4.94	3.23	0.00	33.33**
79128AxRR50	-0.55	-6.74**	-9.55**	5.32*	-3.48	9.48**	6.04	-5.25	16.73**	0.00	-6.67	16.67
79128AxRR55	-1.11	-4.71**	-8.54**	1.46*	-5.88*	3.95	8.86	1.88	13.31**	7.14	0.00	25.00*
79128AxRR65	-1.33	-10.19**	-7.04**	5.42*	-2.53	8.43**	5.51	-3.57	12.93**	3.45	0.00	25.00*
79128AxWGL347	-6.07**	-15.24**	-10.55**	7.59**	2.44	7.02*	14.40**	12.76**	12.55**	0.00	0.00	25.00*
79128AxWGL616	-1.88	-10.29**	-8.04**	7.53**	1.06	8.52**	16.04 **	13.75**	14.83**	0.00	-6.67	16.67
79128AxWGL674	-2.19	-9.14**	-10.05**	4.09	-3.12	6.23*	7.75*	4.01	8.37	-6.25	-11.76	25.00*
79128AxWGL676	-2.93*	-11.65**	-8.54**	-0.80	0.00	2.99	7.00	6.18	4.56	-17.65**	-26.32**	16.67

Hybrid	Days to 50% flowering			Plant height(cm)			Panicle length(cm)			Effective tillers		
	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H3
79128AxWGL705	-3.21*	-11.71**	-9.05**	0.85	-2.84	0.97	10.55**	10.12*	7.6	3.45	0.00	25.00*
79128AxWGL739	-4.73**	-4.73**	-19.10**	-2.81	-5.05	-5.97	4.02	3.92	0.76	-9.68	-12.5	16.67
79128AxWGL810	-4.84**	-12.81**	-11.06**	0.60	-6.26*	2.55	12.02**	10.73	9.89*	3.45	0.00	25.00*
79128AxWGL1063	-1.39	-6.84**	-11.06**	7.12**	-3.84	14.22**	19.43**	15.60**	19.77**	-3.45	-6.67	16.67
79128AxMTU1156	1.73	-0.56	-11.56**	0.74	-5.46	1.84	4.53	5.85	3.04	-9.68	-12.5	16.67
79128AxMTU11-320-20	-4.47**	-9.52**	-14.07**	-5.34*	-14.15**	-0.35	-3.29	-7.05	-2.28	7.14	0.00	25.00*
68897AxRR3	-12.79**	-13.29**	-24.62**	-4.16	-13.99**	2.02	8.71*	8.1	9.13*	0.00	-6.25	25.00*
68897AxRR15	7.60**	7.60**	-7.54**	-0.27	-10.12**	5.62	10.56**	6.74	14.45**	10.34	6.67	33.33**
68897AxRR17	-13.64**	-16.02**	-23.62**	-10.66**	-18.91**	-6.23	-2.32	-4.71	0.00	0.00	-6.25	25.00*
68897AxRR23	-5.51**	-14.29**	-9.55**	-9.54**	-17.28**	-5.88	10.29**	9.36*	11.03**	33.33**	15.79*	83.33**
68897AxRR32	-8.88**	-9.94**	-22.61**	2.60	2.41	-3.07	13.71**	7.43	7.22	26.67**	18.75*	58.33*
68897AxRR50	-4.40**	-9.84**	-12.56**	0.59	-7.89**	4.48	3.67	-6.17	15.59**	33.33**	28.57**	50.00**
68897AxRR55	-3.87**	-8.90**	-12.56**	-15.48**	-21.66**	-13.48**	2.07	-3.16	7.70	48.15**	42.86**	66.67**
68897AxRR65	-3.98**	-12.14**	-9.05**	6.28*	-1.82	9.22**	7.62*	-0.32	16.73**	7.14	7.14	25.00*
68897AxWGL347	-7.09**	-15.71**	-11.06**	7.69**	2.44	7.02*	2.48	2.48	2.28	-3.45	-6.67	16.67
68897AxWGL616	-2.93*	-10.78**	-8.54**	3.87	-2.45	4.74	3.41	2.82	3.80	18.52*	14.29	33.33**
68897AxWGL674	-5.43	-11.68**	-12.56**	1.85	-5.28	3.86	4.01	1.82	6.08	3.23	-5.88	33.33**
68897AxWGL676	-3.45*	-11.65**	-8.54**	-8.93**	-16.52**	-5.53	7.77*	7.05	6.84	27.27**	10.53	75.00**
68897AxWGL705	-6.38 **	- 14.15**	-11.56**	2.28	-1.55	0.35	8.18*	7.05	6.84	21.43**	21.43	41.67**
68897AxWGL739	6.47 **	5.85**	-9.05**	4.4 5	1.95	0.97	12.57**	10.86*	10.65*	-6.67	-12.5	16.67
68897AxWGL810	-6.95**	-14.29**	-12.56**	-1.29	-8.11**	0.53	5.83	5.52	5.32	0.00	0.00	16.67
68897AxWGL1063	-3.60*	-8.42**	-12.56**	8.03**	-3.10	15.1**	11.40**	9.36*	13.31**	7.14	7.14	25.00*
68897AxMTU1156	-2.30	-3.95*	-14.57**	-0.22	-6.44*	0.79	8.37*	8.16	8.37*	0.00	-6.25	25.00*
68897AxMTU11-320-20	-3.33*	-7.94**	-12.66**	-5.01*	-13.92**	-0.09	7.61*	4.88	10.27*	11.11	7.14	25.00*

Hybrid	Flag leaf length(cm)			Flag leaf width(cm)			Number of grains per panicle			Test weight (g)		
	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3
79156AxRR3	18.90**	10.72	19.65**	-18.75	-21.21	-16.13	8.55	-4.76	13.64	6.78	-4.26	2.51
79156AxRR15	21.67**	21.18**	13.85*	22.58*	15.15	22.58	39.74**	42.02**	23.86*	-11.65**	-29.11**	-0.46
79156AxRR17	3.31	-5.39	6.05	-5.88	-8.57	3.23	9.44	11.04	-2.84	9.41**	-8.50**	15.53**
79156AxRR23	32.91**	25.00**	32.24**	-25.71*	-29.73**	-16.13	27.78**	7.54	41.76**	26.57*	18.54**	15.30**
79156AxRR32	0.00	-2.56	-4.28	12.28	-3.03	3.23	-20.46	-17.35	-30.97*	26.62**	13.17**	-3.88
79156AxRR50	30.83**	18.72**	35.77**	-11.76	-14.29	-3.23	15.5	2.18	19.6	6.7	-5.22	3.65
79156AxRR55	29.37**	26.68**	23.17**	-44.44**	-48.72**	-35.48**	6.65	-4.94	9.38	18.34	8.52*	10.50*
79156AxRR65	10.34*	-.3.26	19.65**	7.04	0.00	22.58	2.25	-12.05	9.94	22.31**	9.05*	18.26**
79156AxWGL347	16.31**	15.08*	9.57	-11.43	-16.22	0.00	72.01**	58.99**	43.18**	-6.1	-21.06**	-1.6
79156AxWGL616	23.57**	21.78**	16.88**	-13.43	-14.71	-6.45	46.19**	34.39**	44.32**	24.65**	19.85**	10.27*
79156AxWGL674	3.77	3.49	-3.02	-23.29*	-30.00**	-9.68	-0.38	-16.6	11.36	7.81*	0	-0.68
79156AxWGL676	8.58	4.32	-2.77	16.67	-23.08*	-3.23	22.27*	13.51	19.32	24.52**	22.85**	4.34
79156AxWGL705	12.71*	7.84	0.50	-40.85**	-44.74**	-32.26*	-0.25	-17.53*	13.64	13.47**	5.03	4.79
79156AxWGL739	3.56	-2.16	2.52	-17.81	-25	-3.23	24.30*	16.57	19.89	16.63**	6.95	8.90*
79156AxWGL810	11.35*	10.03	5.04	-8.82	-11.43	0.00	45.95*	-50.78**	-46.02**	38.72**	33.87**	13.70**
79156AxWGL1063	2.25	-8.88	8.56	-11.11	-25.00**	16.13	9.73	-9.28	25.00*	7.75*	-3.21	3.2
79156AxMTU1156	-0.69	-2.10	-8.82	-14.75	-21.21	-16.13	4.51	-5.60	5.4	23.90**	15.93**	13.01**
79156AxMTU11-320-20	-16.79**	-25.22**	-12.59	-31.03**	-44.44**	-3.23	32.07**	31.86*	18.75	3.5	-10.72**	4.57
79128AxRR3	-15.56**	-24.13**	-18.01*	-25.93*	-35.48**	-35.48**	1.24	-22.38*	-7.39	13.92**	2.99	10.27*
79128AxRR15	24.76**	19.57**	12.34*	53.85**	37.93**	29.03*	82.67**	57.98**	37.78**	7.04*	-24.88**	5.48
79128AxRR17	11.05*	-1.8	10.08	0	-17.14	-6.45	51.13**	30.52*	14.2	7.08*	-9.76**	13.93**

79128AxRR23	27.30**	15.48*	22.17**	-10	-27.03*	-12.9	23.84*	-8.19	21.02	5.09	-0.7	-3.42
79128AxRR32	17.49**	10.26	8.31	27.66	25	-3.23	23.20*	17.35	-1.99	33.33**	18.21**	2.28
79128AxRR50	31.91**	15.64**	32.24**	28.28*	6.29	20	57.23**	21.36*	42.05**	34.27**	20.25	31.51**
79128AxRR55	38.46**	30.57**	26.95**	-3.23	-23.08*	-3.23	-7.47	-28.15**	-17.33	25.82**	16.37**	18.49**
79128AxRR65	3.00	-12.63*	8.06	14.75	-7.89	12.9	38.86**	4.77	30.97*	14.52**	2.95	11.64**

Hybrid	**Flag leaf length(cm)**			**Flag leaf width(cm)**			**Number of grains per panicle**			**Test weight (g)**		
	H_1	**H_2**	**H_3**	**H_1**	**H_2**	**H_3**	**H_1**	**H_2**	**H_3**	**H_1**	**H_2**	**H_3**
79128AxWGL347	28.06**	21.96**	16.12*	0	-18.92	-3.23	92.29**	76.21**	34.66**	-6.59*	-20.88**	-1.37
79128AxWGL616	39.42*	32.28**	26.95**	5.26	-11.76	-3.23	56.15**	24.34*	33.52**	23.27**	19.60**	10.05*
79128AxWGL674	27.17**	22.04**	14.36*	-4.76	-25.00*	-3.23	35.45**	0	33.52**	2.21	-4.37	-5.02
79128AxWGL676	27.09**	26.90**	9.32	-3.23	-23.08*	-3.23	42.42**	14.32	20.17	25.78**	22.96**	6.39
79128AxWGL705	21.47**	20.76**	4.03	-21.31	-36.84**	-22.58	11.14	-18.76*	11.93	19.85**	11.90**	11.64**
79128AxWGL739	-1.58	-10.34	-6.05	-26.96*	-42.50**	-25.81	10.24	-10.77	-8.24	14.91**	6.28	8.22*
79128AxWGL810	23.99**	17.94**	12.59*	3.45	-14.29	-3.23*	17.38	-7.25	1.7	54.21**	47.49**	27.63**
79128AxWGL1063	22.70**	5.71	2594**	12.68	-16.67*	29.03	63.33**	19.38*	64.49**	17.49**	6.42	13.47**
79128AxMTU1156	1.28	-1.11	-10.58	-5.88	-14.29	-22.58	-20.26	-37.40**	-30.11*	51.86**	43.33**	39.73**
79128AxMTU11-320-20	-14.39**	-25.65**	-13.10*	-35.06**	-53.70**	-19.35	1.85	-12.97	-21.88	26.01**	9.55**	28.31**
68897AxRR3	-14.66**	3.03	11.34	-29.82*	-35.48**	-35.48**	-22.62	-38.10**	-26.14*	3.08	2.75	10.73**
68897AxRR15	17.20**	12.33	5.54	45.45**	37.93**	29.03*	83.90**	67.43**	46.02**	-16.10**	-25.85**	4.11
68897AxRR17	-3.94	-15.06**	-4.79	-27.87*	-37.14**	-29.03*	15	4.55	-8.52	5.56	-2.17	23.52**
68897AxRR23	8.4	-1.67	4.03	-7.94	-21.62*	-6.45	-33.52**	-48.71**	-32.39**	-10.69**	-15.04**	-8.45*
68897AxRR32	3.01	-3.33	-5.04	20	15.38	-3.23	-7.69	-14.29	-28.41*	13.73**	-7.84*	-0.68
68897AxRR50	1.26	-11.23*	1.51	-1.64	-14.29	-3.23	-8.13	-25.97*	-13.35	15.25**	14.41**	25.11**
68897AxRR55	13.19*	6.74	3.78	-5.23	-21.03*	-0.65	-22.07*	-36.79**	-27.27*	-9.37**	-11.86**	-5.02
68897AxRR65	5.16	-10.79*	10.33	9.38	-7.89	12.9	-24.86*	-40.91**	-26.14*	3.08	3.37	12.10**
68897AxWGL347	1.67	-3.17	-7.81	-7.94	-21.62*	-6.45	7.87	4.46	-20.17	-11.98**	-17.95**	2.28
68897AxWGL616	10.65	4.99	0.76	-6.67	-17.65	-9.68	-8.89	-24.07*	-18.47	3.54	-4.03	3.42
68897AxWGL674	12.89*	8.33	1.51	-9.09	-25.00*	-3.23	-3.88	-26.17**	-1.42	0.33	-3.6	3.88
68897AxWGL676	22.11**	21.93*	5.04	-7.69	-23.06**	-3.23	13.18	-4.86	0	8.87*	-3.81	3.65
68897AxWGL705	28.53**	27.78**	10.08	-15.62	-28.95**	-12.9	-12.62	-33.61**	-8.52	0.99	-2.75	4.79
68897AxWGL739	13.72*	3.61	8.56	-24.24*	-37.50**	-19.35	27.36*	8.01	11.08	-4.79	-7.42*	-0.23
68897AxWGL810	17.06**	11.35	6.3	-1.64	-14.29	-3.23	44.20**	19.17	30.68**	10.51**	-4.24	3.2
68897AxWGL1063	9.2	5.92	12.09	8.11	-16.67*	-29.03*	52.51**	15.88	59.66**	9.05**	8.47*	16.89**
68897AxMTU1156	11.27	8.64	-1.76	-25.93*	-28.57*	-35.48**	36.43**	11.96	25.00*	-1.45	-6.14	1.14
68897AxMTU11-320-20	-8.68	-20.69**	-7.3	-37.50**	-53.70**	-19.35	54.93**	39.24**	25.00*	1.73	-2.34	14.38**

Hybrid	**Unfilled seeds/panicle**			**Self fertility(%)**			**Grain yield per plant (g)**			**Hulling recovery%**		
	H_1	**H_2**	**H_3**	**H_1**	**H_2**	**H_3**	**H_1**	**H_2**	**H_3**	**H_1**	**H_2**	**H_3**
79156AxRR3	8.16	-17.19	-39.77*	-1.5	-5.06	0.86	43.11**	-3.3	56.18**	-0.28	-3.02	0.06
79156AxRR15	-20.00	-46.88	-61.36**	4.93	2.1	6.37	115.33**	66.13**	73.60**	-2.5	-4.21*	-3.18
79156AxRR17	-28.81	-34.38	-52.27*	1.74	0.95	1.08	-8.11	-40.52**	14.61	-0.33	-0.59	-3.05
79156AxRR23	29.82	15.63	-15.91	-1.07	-3.39	-0.08	-1.9	-35.51**	16.29	-2.29	-3.32	-3.68*
79156AxRR32	136.25**	96.88**	114.77**	-10.75**	-15.86**	-17.07**	-44.64**	-57.45**	55.06**	-1.56	-3.65	-6.04**
79156AxRR50	-18.18	-29.69	-48.86*	2.71	-0.98	5.16	-2.63	-35.85**	14.61	0.65	-0.32	-0.89
79156AxRR55	219.70**	210.29**	139.77**	-26.41**	-29.75**	-23.85**	16.67	-19.93*	21.91	-2.51	-2.67	-5.08**
79156AxRR65	48.48*	44.12	11.36	-7.32*	-7.78*	-9.11*	45.98**	2.83	42.70**	-1.7	-2.08	-4.51*
79156AxWGL347	-4.83	-14.81	-21.59	-0.49	-2.67	0.33	41.03**	-4.84	54.49**	0.03	-2.06	-0.32
79156AxWGL616	-49.66*	-55.42*	-57.95**	8.48*	8.26*	6.71	42.09**	7.65	18.54	0.61	-0.45	-0.83
79156AxWGL674	23.53	16.67	-4.55	-2.62	-4.48	-5.85	107.12**	53.85**	79.78**	-4.04*	-6.22**	-4.19*
79156AxWGL676	-7.14	-18.75	-40.91*	4.66	3.71	2.22	68.24**	12.25	90.45**	3.47*	2.97	1.4
79156AxWGL705	88.24**	50.00	909.00	-6.77*	-7.36	-7.51	84.57**	34.08**	67.98**	2.39	0.06	2.22
79156AxWGL739	-16.23	-37.01**	-9.09	-0.47	-2.55	-3.94	38.96**	3.38	20.22	2.4	1.8	0.44
79156AxWGL810	-26.05	-31.25	50.00*	-6.15	-6.55	-7.09	14.75	-21.32*	20.22	2.26	1.48	0.51
79156AxWGL1063	-49.51	-59.38*	7045**	-5.48	-8.75*	-3.37	58.10**	16.36	39.89**	-2.29	-2.8	-5.21**
79156AxMTU1156	-25.30	-44.19**	-18.18	8.85*	0.78	-0.66	23.54*	-19.21*	48.88**	-4.48**	-5.48**	-5.84**
79156AxMTU11-320-20	-55.93*	-59.38*	-70.45**	8.41*	7.25	8.03*	66.04**	21.66	48.31**	-0.45	-2.26	-1.08
79128AxRR3	-65.22*	-72.41*	-81.82**	8.47*	0.66	6.93	-32.30**	-50.61**	-20.22	-3.21*	-5.17**	-2.16
79128AxRR15	-59.49	-72.41*	-81.82**	13.43**	6.22	10.66**	45.28**	24.19	29.78*	-2.25	-3.27	-2.22
79128AxRR17	-32.14	-34.48	-56.82**	7.42*	2.48	2.62	37.26**	-4.96	83.15**	-0.29	-1.28	-2. 29
79128AxRR23	5.56	-1.72	-35.23	3.88	-2.39	0.95	1.99	-28.04**	29.78*	0.06	-0.26	- 0. 64
79128AxRR32	42.86*	14.58	25.00	-8.77*	-10.61*	-18.71**	-10.94	-24.2	-19.94	-3.30*	-6.03**	-6.99**
79128AxRR50	61.54*	44.83	-4.55	-3.16	-10.12**	-4.55	4.00	-26.42**	31.46*	-0.42	-0.64	-1.21
79128AxRR55	136.51**	119.12**	69.32**	-4.08**	-30.20**	-24.33**	-35.98**	-52.40**	-27.53*	4.08*	3.15	2.1
79128AxRR65	58.73*	47.06	13.64	0.04	-3.37	-5.70	24.54*	-4.45	32.58*	0.36	-0.77	-1.78
79128AxWGL347	-2.16	-16.05	-22.73	1.67	-4.32	-1.37	-0.24	-27.34**	17.98	1.46	0.06	1.84
79128AxWGL616	-47.52*	55.42*	-57.95**	11.68**	7.56	5.90	82.32**	52.55**	67.98**	3.01	2.68	2.29

Hybrid	Unfilled seeds/panicle			Self fertility(%)			Grain yield per plant (g)			Hulling recovery%		
	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3
79128AxWGL674	126.15**	104.17**	67.05**	-6.00	-8.32*	-13.07**	29.12*	5.53	23.31	-2.84	-4.35*	-2.29
79128AxWGL676	62.26*	48.28	-2.27	1.16	-1.90	-5.05	-19.59*	-42.22**	-1.97	-0.26	-0.51	-1.52
79128AxWGL705	56.25	29.31	-14.77	0.33	-4.14	-4.30	33.24**	6.05	32.87*	-1.77	-3.3	1.21
79128AxWGL739	-0.54	-27.56*	4.55	-4.06	-5.85	-11.07**	4.42	-14.49	-0.56	0.23	0.06	-0.95
79128AxWGL810	16.81	13.79	-25.00	0.52	-3.77	-4.33	4.46	-22.43*	18.54	2.66	2.63	1.65
79128AxWGL1063	48.45	24.14	-18.18	2.32	-4.91	0.70	67.63**	35.51**	62.92**	2.83	1.54	0.51
79128AxMTU1156	10.16	-20.16	17.05	-2.97	-6.70	-15.16**	0.87	-29.27**	30.34*	-4.16*	-4.46*	-4.83**
79128AxMTU11-320-20	-30.36	-32.76	-55.68**	6.16	1.00	1.74	-2.01	-21.2	-3.93	0.16	-0.94	0.25
68897AxRR3	-67.27*	-76.32**	-79.55**	9.32**	0.92	7.21	13.39	-18.26*	32.02*	-4.22**	-4.93**	-1.91
68897AxRR15	17.53	-25.00	-35.23	5.90	-1.36	2.76	95.53**	64.52**	71.91**	-2.91	-3.19	-1.59
68897AxRR17	-56.92*	-63.16**	-68.18**	10.91**	5.24	5.38	21.28*	-16.91*	60.11**	2.14	-0.19	1.46
68897AxRR23	-22.22	-35.53	-44.32*	3.00	-3.74	-0.43	98.21**	38.32**	149.44**	1.39	0.37	2.03
68897AxRR32	24.42	11.46	21.59	-3.46	-4.87	-14.48**	104.44**	71.28**	80.90*	3.19	-1	0.64
68897AxRR50	-34.43	-47.37*	-54.55**	5.35	-2.74	3.29	15.96	-18.87*	44.94**	-0.73	-1.81	-0.19
68897AxRR55	-2.78	-7.89	-20.45	-9.43**	-17.16**	-10.20**	54.77**	13.65	73.03**	1.21	-1	0.64
68897AxRR65	45.83*	38.16	19.32	3.73	-0.35	-2.76	50.80**	14.17	58.43**	3.75*	1.25	2.92
68897AxWGL347	-37.58	-39.51	-44.32*	4.79	-1.90	1.11	-16.83	-40.14**	-2.81	-5.87**	-5.93**	-4.26*
68897AxWGL616	-6.92	-10.84	-15.91	-4.30	-8.33*	-10.01*	21.98	0.51	10.67	0.44	-0.56	1.08
68897AxWGL674	122.97**	117.11**	87.50**	-16.01**	-18.18**	-22.42**	60.60**	29.33*	51.12**	-4.55**	-4.79**	-2.73
68897AxWGL676	69.35**	38.16	19.32	-5.42	-8.79*	-11.72**	62.24**	15.23	95.51**	-3.49*	-5.00**	-3.43
68897AxWGL705	10.53	-17.11	-28.41	2.73	-2.38	-2.54	67.71**	31.61**	64.89**	-3.87*	-4.10*	-2.03
68897AxWGL739	29.06	3.15	48.86*	-8.80*	-11.00**	-15.94**	42.51**	14.98	33.71*	-0.73	-2.19	-0.57
68897AxWGL810	-0.76	-14.47	-26.14	4.82	-0.20	-0.77	-21.30*	-42.28**	-11.8	0.16	-1.13	0.51
68897AxWGL1063	2.61	-22.37	-32.95	5.20	-2.74	2.99	94.13**	54.67**	85.96**	0.48	-2.06	-0.44
68897AxMTU1156	-10.24	-28.68*	4.55	6.84	3.31	-7.13	10.77	-23.17**	41.57**	-1.01	-2	-0.38
68897AxMTU11-320-20	41.54	21.05	4.55	-2.11	-7.37	-6.69	79.07**	41.94**	73.03**	-5.23**	-5.44**	-3.88*

Hybrid	Milling recovery %			Head rice recovery %			Kernel length (mm)			Kernel width (mm)		
	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3
79156AxRR3	-2.75	-13.65**	-4.65	-18.09**	-20.24**	-15.83**	-1.26	-0.09	10.25**	-9.62**	-20.42**	-15.31**
79156AxRR15	22.02**	17.16**	8.62*	62.71**	20.60**	20.60**	-8.28**	-10.92**	-1.71	-3.65	-15.91**	-8.64*
79156AxRR17	-11.40**	-11.86**	-23.69**	-56.07**	-57.91**	57.91**	-1.89	-4.11	10.82**	15.71**	8.87*	0
79156AxRR23	-16.1**	-24.33**	-19.34**	-58.36**	-63.07**	-52.26**	14.26**	3.01	13.66**	5.11	0.84	-11.11**
79156AxRR32	-7.3	-10.06*	-22.94**	-39.03**	-39.95**	-39.95**	-0.05	-12.73**	-3.7	5.83	2.44	-17.04**
79156AxRR50	-4.59	-8.71*	-14.39**	29.67**	16.96	16.96**	2.84	-0.16	16.98**	3.31	-8.67*	-3.7
79156AxRR55	-10.42**	-16.54**	-17.17**	-46.73**	-53.82**	-37.06**	5.82	-3.01	7.02	-3.14	12.35**	-12.35**
79156AxRR65	-7.02*	-15.77**	-11.09**	-41.96**	-47.05**	-35.80**	3.1	0	10.34**	7.92	5.87	-10.86**
79156AxWGL347	-4.44	-13.89**	-8.02*	-0.67	-7.54	-7.54	3.98	-2.32	7.78*	11.42**	11.25*	-9.63*
79156AxWGL616	8.59*	0.75	0.9	-2.87	-17.01**	17.09**	4.01	-0.77	9.49**	8.84*	8.84	-11.85**
79156AxWGL674	0.84	-6.76	-5.92	-5.47	-14.89*	6.28	7.73**	3.1	13.76**	11.49**	9.45*	-11.36**
79156AxWGL676	3.34	-6.21	-1.42	-27.70**	-39.44**	-10.30*	4.78	-1.98	8.16*	4.22	-0.28	-11.60**
79156AxWGL705	6.55	-2.95	1.2	-17.16**	-23.32**	-9.92*	4.53	2.24	12.81**	5.26**	3.86	-13.58**
79156AxWGL739	3.84	-2.68	-4.65	0.27	-11.45**	15.58**	2.9	0.77	11.20**	7.14	0.81	-7.41
79156AxWGL810	4.23	-7.69*	2.55	-13.38**	-27.59**	7.79	13.46**	4.73	15.56**	15.26**	12.10**	-3.95
79156AxWGL1063	10.77**	8.67*	-3.22	-44.79**	-46.39**	-43.09**	1.44	-2.92	7.12*	2.6	-6.95	-7.41
79156AxMTU1156	-2.93	-8.84	-21.89**	-5.08	-23.74**	-23.74**	-1.24	-4.04	5.88	0.43	5.15	-13.58**
79156AxMTU11-320-20	-3.85	-4.8	-16.79**	-45.62**	-48.87**	-48.87**	-0.57	-1.89	8.25*	4.84	-8.24*	-0.99
79128AxRR3	-9.59**	-15.82**	-7.05	-19.58**	-35.95**	-32.41**	-3.55	-6.47*	6.93*	-1.07	-14.39**	-8.89*
79128AxRR15	4.8	3.23	-1.72	62.36**	43.78**	-10.05*	-7.08	-11.29**	1.42	-0.4	-14.55**	-7.16
79128AxRR17	-1.77	-6.22	-10.72**	-28.77**	-40.05**	-45.10**	-8.71**	-9.20**	4.93	9.46*	1.08	-7.16
79128AxRR23	1.34	-4.08	2.25	10.41*	-18.08**	5.9	4.72	-7.05*	6.26	3.57	-2.52	-14.07**
79128AxRR32	2.69	-5.2	-9.75	-48.35**	-57.51**	-58.79**	-9.70**	-22.32**	-11.20**	20.26**	18.73**	-7.65*
79128AxRR50	2.42	1.65	-3.22	22.14**	8.59	-12.69*	1.15	-0.08	17.08**	4.04	-9.60*	-4.69
79128AxRR55	1.46	-0.6	-1.35	-29.63**	-48.66**	-30.33**	12.97**	1.91	16.51**	-1.94	-12.84**	-12.84**
79128AxRR65	-7.99*	-12.50**	-7.65*	7.31	-18.65**	-1.38	4.44	-0.41	13.85**	12.50**	8.21	-8.89*
79128AxWGL347	-7.98*	-12.98**	-7.05	18.41**	2.19	-11.93*	-2.02	-9.46**	3.51	7.76	5.47	-14.32**
79128AxWGL616	4.22	1.65	1.8	18.57**	-14.43**	20.73**	-0.75	-6.89*	6.45	7.93	5.79	-14.32**

Hybrid	Milling recovery %			Head rice recovery %			Kernel length (mm)			Kernel width (mm)		
	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3
79128AxWGL674	-15.83**	-18.20**	-17.47**	-43.03**	-57.24**	-46.61**	-5.38	-10.95**	1.80	7.45	7.28	-16.30**
79128AxWGL676	-7.56*	-11.91**	-7.42	-34.05**	53.1	-30.53	-1.89	-9.71**	3.23	1.78	-4.46	-15.31**
79128AxWGL705	-9.21**	-13.16**	-9.45*	-24.91**	-42.46**	-32.41**	3.58	-0.41	13.85**	11.96**	8.31	-9.88*
79128AxWGL739	-4.93	-6.27	-8.17*	-26.09**	-45.33**	-28.64**	1.21	-2.57	11.39**	3.64	-4.3	-12.10**

79128AxWGL810	-1.45	-8.50*	1.65	7.90*	-23.38**	14.07**	3.88	-5.64	7.87*	5.44	0.58	-13.83**
79128AxWGL1063	10.82**	7.24	2.1	-21.52**	-37.63**	-33.79**	2.91	-3.15	10.72**	10.58**	-1.49	-1.98
79128AxMTU1156	20..5**	7.48	2.32	65.95**	63.45**	2.26	1.74	2.82	11.10**	8.77*	0.81	-8.15*
79128AxMTU11-320-20	6.40	2.05	-2.85	15.60**	-1.14	-12.94**	-2.95	-5.89	7.59*	-4.79	-18.08**	-11.60**
68897AxRR3	-25.11**	-29.12**	-21.74**	-46.91**	-52.38	-49.75**	2.01	0.71	8.16	-8.24*	-16.01**	-10.62**
68897AxRR15	-1.22	-4.33	-5.7	97.91**	55.92**	30.65**	-4.87	-5.17	-0.76	-1.25	-10.45**	-2.72
68897AxRR17	0.44	-5.7	-7.05	-36.82**	-39.51**	-44.60**	1.77	-3.04	12.05**	0.27	-1.61	-9.63*
68897AxRR23	-2.16	-5.84	0.37	18.99**	-1.94	26.76**	6.04	-2.09	2.47	4.34	4.19	-7.90*
68897AxRR32	6.44	-3.027	-4.65	-0.76	-7.51	-10.30*	-5.43	-15.50**	-11.57**	8.57	0.84	-10.86**
68897AxRR50	-2.73	-5.1	-6.45	5.28	3.15	-13.57**	1.63	-3.81	12.71**	-5.99	-13.58**	-8.89*
68897AxRR55	2.61	2.27	1.5	14.27**	-7.74*	25.75**	24.23**	16.68**	22.11**	0.39	-5.43	-5.43
68897AxRR65	1.07	-2.27	3.15	-5.88	-20.41**	-3.52	-12.93**	-13.33**	-9.30**	8.73*	6.15	-6.17
68897AxWGL347	-7.37*	-10.95**	-4.87	-24.32**	-25.36**	-35.68**	-0.24	-3.9	0.57	6.26	1.96	-9.88*
68897AxWGL616	9.17**	8.31*	8.47*	-1.12	-21.19**	11.18*	9.87**	7.52	12.52**	7.58	3.07	-8.89*
68897AxWGL674	3.27	2.08	3	-7.16	-22.43**	-3.14	10.06**	8.07*	13.09**	7.42	1.12	-10.62**
68897AxWGL676	-4.53	-7.49*	-2.77	26.33**	-1.1	46.48**	14.27**	9.61**	14.71**	-6.28	-6.41	-17.04**
68897AxWGL705	0.37	-2.37	1.8	24.97**	7.06	25.75**	7.99**	7.55*	13.47**	5.32	2.23	-9.63*
68897AxWGL739	-4.73	-5.02	-6.37	5.63	-13.28**	13.19**	1479**	14.77**	20.78**	1.92	0.00	-8.15*
68897AxWGL810	-13.76**	-18.62**	-9.60*	-9.50**	-29.28**	5.28	7.81*	1.99	6.74	1.28	-0.28	-11.85**
68897AxWGL1063	-9.15*	-13.54**	-14.77**	-41.14**	-47.34**	-44.10**	3.14	1.27	5.98	8.28*	2.23	1.73
68897AxMTU1156	0.39	-11.48**	-12.74**	-15.30**	-26.99**	-38.82**	3.82	3.54	8.35*	-2.89	-4.34	-12.84**
68897AxMTU11-320-20	3.99	-1.9	-3.3	2.49	0	-11.93*	4.34	3.00	10.63**	-8.93*	-17.16**	-10.62**

Hybrid	**Length/ Breadth ratio**			**Kernel length after cooking (mm)**			**Kernel breadth after cooking (mm)**			**Kernel elongation ratio**		
	H_1	**H_2**	**H_3**	**H_1**	**H_2**	**H_3**	**H_1**	**H_2**	**H_3**	**H_1**	**H_2**	**H_3**
79156AxRR3	9.80*	-4.51	30.38**	-3.21	-7.55	-3.68	-4.97	-7.53	-21.82**	-4.03	-7.00	12.74**
79156AxRR15	-7.28	-21.13**	7.69	-2.44	-5.43	-1.47	0.00	-13..33**	-5.45	6.58	6.58	0.00
79156AxRR17	-15.31**	-18.59**	11.15	0.11	-1.91	2.21	-3.48	-14.16**	-11.82*	1.72	-2.47	-8.49
79156AxRR23	8.19	-6.06	28.27**	12.66**	-0.14	4.04	22.62**	17.05**	-6.36	-1.26	-2.88	-8.88
79156AxRR32	-5.1	-14.79**	16.35*	-11.97**	-21.67**	-18.38**	15.79**	7.84	0.00	-12.05**	-14.12*	-15.44**
79156AxRR50	-1.78	-10.85*	21.73**	-1.42	-5.5	7.35	2.13	-4.00	-12.73*	-3.85	-5.20	-8.49
79156AxRR55	6.98	-10.42*	22.31**	16.51**	6.56	11.03*	-3.74	-9.09	-18.18**	10.29*	10.29*	3.47
79156AxRR65	-5.08	-9.15	24.04**	-1.34	-4.02	0.00	6.19	-2.83	-6.36	-40.1	-4.49	-9.65*
79156AxWGL347	-6.83	-12.54*	19.42**	2.42	-5.79	-1.84	4.97	2.15	-13.64**	-1.26	-3.29	-9.27
79156AxWGL616	-4.51	-9.01	24.23**	5.67	0.56	4.78	4.81	-1.01	-10.91*	1.86	1.65	-4.63
79156AxWGL674	-3.04	-5.63	28.85**	1.26	-0.78	3.38	-1.08	-6.12	-16.36	-5.81	-8.20	-9.27
79156AxWGL676	-0.16	-10.42*	22.31**	11.59**	9.74*	14.34**	4.57	-5.50	-6.36	6.23	0.74	5.41
79156AxWGL705	-0.58	-4.08	30.96**	9.41*	5.86	10.29*	-5.00	-15.18**	-13.64**	5.20	4.12	-2.32
79156AxWGL739	-4.51	-11.97*	20.19**	7.21	6.56	11.03*	-2.00	-12.50*	-10.91*	4.05	2.39	-0.77
79156AxWGL810	-2.34	-11.83*	20.38**	13.28**	0.21	44.41	5.49	2.13	-12.73*	0.43	-4.12	-10.04**
79156AxWGL1063	-2.67	-15.21**	15.77*	-9.13*	-16.73**	-13.24**	-14.29**	-22.22**	-23.64**	-10.11*	-13.99**	-19.31**
79156AxMTU1156	-1.84	-9.86*	23.08**	4.43	2.33	6.62	-14.85**	-24.56**	-21.82**	5.91	4.84	0.39
79156AxMTU11-320-20	-7.39	-19.72**	9.62	0.86	-4.38	-0.37	8.11	3.09	-9.09	1.28	-2.47	-8.49
79128AxRR3	-5.27	-20.13**	17.50**	0.54	-6.64	3.31	5.82	4.17	-9.09	4.18	-0.40	-3.86
79128AxRR15	-10.06	-25.75**	9.23	-12.52**	-17.61**	-8.82	-19.44**	27.50**	-20.91**	-5.88	-7.20	-10.42*
79128AxRR17	-17.04**	-23.01**	13.27*	-7.16	-11.63**	-2.21	-11.96*	-18.58**	-16.36**	1.48	-4.00	-7.34
79128AxRR23	0.31	-15.56**	24.23**	-0.77	-14.29**	-5.15	-1.14	-9.38	-20.91**	-4.74	-7.60	-10.81*
79128AxRR32	-24.66**	-34.51**	-3.65	-12.64**	-24.25**	-16.18**	4.04	0.98	-6.36	-3.37	-4.31	-5.79
79128AxRR50	-4.76	-16.34**	23.08**	-3.61	-4.85	8.09	-0.04	-4.00	-12.73*	-4.4	-4.40	-7.72
79128AxRR55	11.90*	-9.02*	33.85**	7.46	-4.32	5.88	-5.64	-7.07	-116.36**	-5.07	-6.40	-9.65*
79128AxRR65	-7.92	-14.90**	25.19**	-7.21	-12.29**	-2.94	-2.97	-7.55	-10.91*	-11.11	-12.00*	-15.06**
79128AxWGL347	-9.37*	-17.78**	20.96**	-6.49	-16.28**	-7.35	-4.76	-6.25	-18.18**	-4.35	-7.60	-10.81*
79128AxWGL616	-8.24	-15.56**	24.23**	1.97	-5.65	4.41	6.67	5.02	-5.45	2.85	1.20	-2.32

Hybrid	**Length/Breadth ratio**			**Kernel length after cooking (mm)**			**Kernel breadth after cooking (mm)**			**Kernel elongation ratio**		
	H_1	**H_2**	**H_3**	**H_1**	**H_2**	**H_3**	**H_1**	**H_2**	**H_3**	**H_1**	**H_2**	**H_3**
79128AxWGL674	-11.90**	-17.25**	21.73**	-8.55*	-12.96**	-3.68	-13.40**	-14.29*	-23.64**	-3.16	-4.30	-5.41
79128AxWGL676	-4.44	-16.99**	22.12**	-7.48	-11.83**	-2.21	-13.17**	-18.33**	-19.09**	-5.95	-9.59*	-5.41
79128AxWGL705	-7.79	-14.12**	26.35**	-5.3	-10.96*	-1.47	-19.23**	-25.00**	-23.64**	-8.2	-10.40*	-13.51**
79128AxWGL739	-3.08	-13.59**	27.12**	-4.3	-7.64	2.21	-14.42**	-20.54**	-19.09**	-5.39	-5.58	-8.49

79128AxWGL810	-2.32	-14.64**	25.58**	4.82	-9.63*	0.00	-5.26	-6.25	-18018**	1.49	-4.40	-7.72
79128AxWGL1063	-8.98	-23.14**	13.08*	1.00	-9.63*	0.00	0.98	-4.63	-6.36	-1.27	-6.80	-10.04*
79128AxMTU1156	-7.28	-17.65**	21.15**	-6.46	-10.96*	-1.47	-8.57	-15.79**	-12.73**	-8.03	-8.40	-11.58*
79128AxMTU11-320-20	-1.40	-17.12**	21.92**	-1.98	-9.63*	0.00	-8.81	-9.28	-20.00**	1.05	-4.00	-7.34
68897AxRR3	10.60*	2.44	21.35**	2.14	1.55	-3.68	-16.83**	-22.94**	-23*64**	-0.22	-0.87	-11.58*
68897AxRR15	-4.67	-13.80*	2.12	-4.03	-6.02	-8.09	-20.52	-24.17**	-17.27**	0.84	-1.65	-7.72
68897AxRR17	1.97	-1.07	24.62**	0.19	-2.94	-2.94	-25.23**	-26.55**	-24.55**	-1.32	-3.03	-13.51**
68897AxRR23	1.67	6.01	11.35	-1.27	-8.24	-13.97**	-6.88	-19.27**	-20.00**	-6.87	-7.66	-16.22**
68897AxRR32	-12.45*	-16.07**	-0.58	0.84	-5.88	11.76**	-20.38**	-22.94**	-23.64**	-6.58	1.57	0.00
68897AxRR50	7.95	4.71	24.04**	-7.09	-15.21**	-3.68	-0.09	-12.84**	-13.64**	-8.11	-11.60*	-14.67**
68897AxRR55	22.92**	9.25	29.42**	3.67	-0.39	-6.62	-15.3**	-19.27**	-20.00**	-16.88**	-18.93**	-23.94**
68897AxRR65	-20.47**	-22.50**	-3.27	-0.57	-2.99	-4.41	-18.14**	-19.27**	-20.00**	14.71**	11.43	5.41
68897AxWGL347	-6.21	-6.74	11.73	7.10	3.53	-2.94	-9.9	-16.51**	-17.27*	7.33	6.87	-3.86
68897AxWGL616	2.14	0.00	23.65**	0.98	0.78	-5.15	-18.27**	-22.02**	-22.73**	-7.82	-9.92	-15.83**
68897AxWGL674	2.48	-1.79	26.92**	-1.33	-4.41	-4.41	-18.84**	-22.94**	-23.64**	-10.47*	-14.87**	-15.83**
68897AxWGL676	21.86**	16.72**	38.27**	11.15**	7.30	8.09	-10.09	-10.19**	-10.91**	-3.19	-10.33*	-6.18
68897AxWGL705	2.51	-0.91	25.77**	1.54	-0.38	-2.94	-15.847**	-16.16**	-15.45**	-5.76	-7.14	-14.67**
68897AxWGL739	-12.76*	11.20*	31.73**	-1.31	-5.71	-2.94	-24.89**	-25.89**	-24.55*	-14.11**	-17.53**	-20.08**
68897AxWGL810	6.06	2.27	21.15**	10.78*	2.75	-3.88	-11.33*	-17.43**	-18.16**	3.1	0.87	-10.04*
68897AxWGL1063	-4.99	-11.85*	4.42	8.72	2.75	-3.88	-21.66**	-22.02**	-22.73**	3.31	1.30	-9.65*
68897AxMTU1156	6.94	5.03	24.42**	-2.85	-5.88	-5.88	-22.87**	-24.56**	-21.82**	-6.47	-9.68	-13.51**
68897AxMTU11-320-20	13.46*	4.71	24.04**	10.02*	9.80*	2.94	-15.53**	-20.18**	-20.91	5.70	4.33	-6.95

Hybrid	**Alkali spreading value**			**Volume expansion ratio**			**Water Uptake(ml)**		
	H_1	**H_2**	**H_3**	**H_1**	**H_2**	**H_3**	**H_1**	**H_2**	**H_3**
79156AxRR3	0	-9.09	-16.67	-16.28	-30.77**	-16.28	49.36**	16.78**	6.75
79156AxRR15	5.26	-9.09	-16.67	-4.55	-19.23	-2.33	2.81	-14.09**	-21.47**
79156AxRR17	0	-9.09	-16.67	-5.26	-13.46	4.65	-12.32**	-20.27**	-27.12**
79156AxRR23	-4.76	-9.09	-16.67	-6.98	-23.08*	-6.98	14.77**	-8.72	-16.56**
79156AxRR32	-5.26	-18.18	-25.00*	2.38	-17.31	0	-24.51**	-34.90**	-40.48**
79156AxRR50	22.22	0.00	-8.33	1.18	-17.31	0	4.55	-7.38	-15.34**
79156AxRR55	-23.81*	-27.27*	-33.33**	5.75	-11.54	6.98	5.22	-18.79**	-25.77**
79156AxRR65	-4.76	-9.09	-16.67	5.62	-9.62	9.3	7.87	-8.05	-15.95**
79156AxWGL347	10.00	0.00	-8.33	-9.09	-23.08*	-6.98	7.38	-12.08**	-19.63**
79156AxWGL616	0.00	-9.09	-16.67	8.16	1.92	23.26	11.51**	4.03	*4.91
79156AxWGL674	-4.76	-9.09	-16.67	4.26	-5.77	13.95	-21.14**	-34.90**	-40.49**
79156AxWGL676	4.35	0.00	0.00	3.85	3.85	25.58	7.84*	5.10	1.23
79156AxWGL705	-9.09	-9.09	-16.67	-6.42	-10.53	18.6	-38.08**	-42.53**	-38.65**
79156AxWGL739	-23.81*	-27.27*	-33.33**	26.32*	-15.38	39.53**	-13.01**	-14.77**	-22.09**
79156AxWGL810	15.79	0.00	-8.33	6.98	-11.54	6.98	7.41	-2.68	-11.04**
79156AxWGL1063	-4.76	-9.09	-16.67	-22.89	-38.46	-25.58	-9.24	-27.52**	-33.74**
79156AxMTU1156	-5.26	-18.18	-25.00*	19.1	1.92	23.26	18.60**	2.68	-6.13
79156AxMTU11-320-20	-5.26	-18.18	-25.00*	1.2	-19.23	-2.33	18.10**	-8.05	-15.95**
79128AxRR3	-23.81*	-33.33**	-33.33**	59.46**	47.50**	37.21**	33.60**	0.00	3.68
79128AxRR15	-20	-33.33**	33.33**	71.05**	62.50**	51.16**	12.27**	-10.65**	-7.36
79128AxRR17	-4.76	-16.67	-16.67	22.89	18.6	18.6	20.27**	3.55	7.36
79128AxRR23	0.00	-8.33	-8.33	51.35**	40.00**	30.23*	36.96**	4.14	7.98
79128AxRR32	-10	-25.00*	-25.00*	44.44**	30.00*	20.93	26.35**	3.55	7.36
79128AxRR50	-15.79	-33.33**	-33.33**	17.81	7.5	0	-4.93	-20.12**	-17.18**
79128AxRR55	-27.27**	-33.33**	-33.33**	41.33**	32.5	23.26	12.80**	-16.57**	-13.50**
79128AxRR65	-45.45**	-50.00**	-50.00**	61.04**	55.00**	44.19**	14.60**	-7.10	-3.68

Hybrid	Alkali spreading value			Volume expansion ratio			Water Uptake(ml)		
	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3
79128AxWGL347	-23.81*	-33.33**	-33.33**	18.42	12.5	4.65	8.33	-15.38*	-12.27
79128AxWGL616	-14.29	-25.00*	-25.00*	2.33	-4.35	2.33	10.74**	-2.37	1.23
79128AxWGL674	-27.27**	-33.33**	-33.33**	14.63	11.9	9.30	-3.01	-23.67**	-20.86**
79128AxWGL676	-8.33	-8.33	-8.33	-10.87	-21.15	-4.65	7.36*	3.55	7.36
79128AxWGL705	4.35	0.00	0.00	-11.34	-24.56*	0.00	2.04	0.57	7.36
79128AxWGL739	-27.27**	-33.33**	-33.33**	1.2	-2.33	-2.33	-2.56	-10.06*	-6.75**
79128AxWGL810	0.00	-16.67	-16.67	21.62	12.5	4.65	-1.38	-15.38**	-12.27**
79128AxWGL1063	45.45**	-50.00**	-50.00**	7.04	-5.00	-11.63	7.75	-17.75**	-14.72**
79128AxMTU1156	0.00	-16.67	-16.67	42.86**	37.50**	27.91*	25.90**	3.55	7.36
79128AxMTU11-320-20	-20.00	-33.33**	-33.33**	7.04	-5.00	-11.63	31.75**	-1.78	1.84
68897AxRR3	-23.81*	-33.33**	-33.33**	48.72**	31.82*	34.80**	14.96**	-14.12**	-10.43*
68897AxRR15	-10.00	-25.00*	-25.00*	25.00*	13.64	16.28	-25.93**	-41.18**	-38.65**
68897AxRR17	14.29	0.00	0.00	-28.74*	-29.55*	-27.91	13.01**	-2.94	1.23
68897AxRR23	-45.45**	-50.00**	-50.00**	56.41**	38.64**	41.86**	24.03**	-5.88	-1.84
68897AxRR32	-20.00	-33.33**	-33.33**	42.11**	22.73	25.58	-15.83**	-31.18**	-28.22**
68897AxRR50	5.26	-16.67	-16.67	35.06**	18.18	20.93	22.81**	2.94	7.36
68897AxRR55	-18.18	-25.00*	-25.00*	16.46	4.55	6.98	39.44**	2.94	7.36
68897AxRR65	-27.27**	-33.33**	-33.33**	48.15**	36.36**	39.53**	-12.00**	-28.82**	-25.77**
68897AxWGL347	-14.29	-25.00*	-25.00*	170.00**	145.45**	151.16**	32.08**	2.94	7.36
68897AxWGL616	-4.76	-16.67	-16.67	102.22**	97.83**	11.63**	-2.34	-14.12**	-10.43*
68897AxWGL674	-27.27**	-33.33**	-33.33**	132.56**	127.27**	132.56**	31.09**	2.94	7.36
68897AxWGL676	0.00	0.00	0.00	72.92**	59.62**	93.02**	7.03*	2.94	7.36
68897AxWGL705	-4.35	-8.33	-8.33	90.10**	68.42**	123.26**	-14.53**	-15.52**	-9.82*
68897AxWGL739	-9.09	-16.67	-16.67	175.6**	172.73**	179.07**	-2.88	-10.59**	-6.75
68897AxWGL810	10.00	-8.33	-8.33	176.92**	145.45**	151.16**	-20.96**	-32.35**	29.45**
68897AxWGL1063	-27.27**	-33.33**	-33.33**	121.33**	88.64**	93.02**	-10.42**	-31.76**	-28.83**
68897AxMTU1156	0.00	-16.67	-16.67	75.31**	61.36**	65.12**	25.45**	2.94	7.360
68897AxMTU11-320-20	20.00	0.00	0.00	254.67*	202.27**	-209.30**	10.67*	-17.65**	-14.11**

Table 3: Best hybrids identified for grain yield, yield components and quality traits based on perse performance and standard heterosis in Rice (*Oryza sativa*. L)

S. No	Character	Range of Heterosis best Heterotic cases			Number of hybrids with significant heterotic effect						Hybrids	Mean Performance	Standard Heterosis H3
		H1	H2	H3	H1		H2		H3				
					+ve	-ve	+ve	-ve	+ve	-ve			
1	Days to 50% flowering	-13.64** to 10.20** 68897A X XRR17 to 79156A X RR15	-15.71** to 9.88** 68897A X WGL-347 To 79156A X RR15	-25.13** to 10.05** 79128A X RR3 to 79156A X WGL -739	9	45	6	48	1	53	79128A × RR3 68897A × RR3 68897A × RR17 79128A × RR32 68897A × RR32	74.5 75 76 76.5 77	-25.13** -24.62** -23.62** -23.12** -22.61**
2	plant height (cm)	-23.16** to 10.08** 79128A X RR3 to 79156A X WGL -739	-30.98** to 17.47** 79128A X RR3 to 79156A X MTU 11-320-20	-18.13** to 14.22** 79128A X RR3 to 79128AX WGL1063	36	18	10	44	39	15	79128A × RR3 68897A × RR55 79156A × RR55	93.25 98.55 106.5	-18.13** -13.48** -6.50**
3	Panicle length (cm)	-11.82** to 22.37** 79128A X RR3 to 79156A X WGL 1063	-16.10** to 17.43** 79128A X RR3 to 79156A X WGL 1063	-12.75** to 25.10** 79128A X RR3 to 79156A X RR50	51	3	41	13	50	4	79156A × RR50 79156A × WGL1063 79128A ×WGL 1063 79128A × RR15 79156A × RR15	32.9 32 31.5 31.3 31.15	25.10** 21.67** 19.43** 19.01** 18.44**
4	Effective tillers	-29.03** to 48.15** 79128A X RR3 to 688977A X RR55	-31.25** to 42.86** 79128A X RR3 to 688977A X RR55	-8.33 to 83.33** 79128A X RR3 to 68897A X RR 23	31	23	25	29	53	1	68897A × RR23 68897A × WGL 676 68897A × RR53 79128A × RR23 68897A × RR32	11 8 10 9.5 9.5	83.33** 75.00** 66.67** 58.33** 58.33**
5	Flag leaf	-16.79** to 39.42**	-25.65** to	-18.01** to	46	8	34	20	40	14	79156A × RR50	53.9	35.77**

	length (cm)	791561 X MTU11 -320-20 to 79128A X WGL 616	32.28** 79128A X MTU11-320-20 to 79128A X WGL 616	35.77** 79128A X RR3 to 79156A X RR50							79156A × RR23 79128A × RR55 79128A × WGL 1063 79156A × RR55	52.5 50.4 50 48.9	32.24** 26.95** 25.94** 23.17**
6	Flag leaf width (cm)	-44.44** to 53.85** 79156A x RR55 to 79128A X RR15	-53.70** to 25 79128A X MTU11 -320-20 to 79128A X RR32	-35.48** to 29.03** 79128A X RR3 to 79128A X RR15	18	36	7	47	13	41	79156A × RR55 79156A × WGL 705 68897A × WGL 1063 79128A × WGL 810	1 1.05 2 1.5	-35.48** -32.26** -29.03** -3.23**
7	No. of filled grains per panicle	-33.52** to 92.29** 68897A X RR23 to 79128A X WGL347	-50.78** to 76.21** 79156A XWGL 810 to 79128A X WGL347	-46.02** to 64.49** 79156A X WGL 810 to 79128A X WGL 1063	40	14	27	27	34	20	79128A × WGL 1063 68897A × WGL 1063 68897A × RR15 79156A × WGL 616 79156A × WGL 347	289.5 281.0 257.0 254.0 252	64.49** 59.66** 46.02** 44.32** 43.18**
8	Test weight (gm)	-16.10** to 54.21** 68897A X RR15 to 79128A X WGL810	-29.11** to 47.49** 79156A X RR15 to 79128A X WGL810	-5.02 to 39.73** 79128 A XWGL 674 to 79128A X MTU1156	45	9	28	26	43	11	79128A × MTU 1156 79128A × RR50 79128A × MTU 11-32-20 79128A × WGL 810 68897A × RR2 32	30.6 28.8 28.1 27.95 21.75	39.73** 31.51** 28.31** 27.63** 25.11**
9	Unfilled grains	-67.27* to 219.70** 68897A X RR3 to 79156 A X RR55	-76.32** to210.29** 68897A X RR3 to 79156 A X RR55	-81.82** to 7045** 79128A X RR3 to 79156A X WGL1063	27	27	22	32	19	35	79128A × RR3 68897A × RR3 68897A × RR17 79156A × RR15 79156A × WGL 616	8.0 9.0 14 17 18.5	-81.82** -79.55** -68.18** -61.36** -57.95**
10	Self fertility %	-26.41** to 13.43** 79156A X RR55 to 79128A XRR15	-30.20** to 8.26* 79128AX RR55 to 79156A X WGL 616	-24.33** to 10.66** 79128A X RR55 to 79128 A X RR15	30	24	14	40	21	33	79128A × RR15 79156A × MTI 11-320-20	96.79 94.494	10.66** 8.03**
11	Grain yield per plant	-44.64** to 115.33** 79156A X RR32 to 79156AX RR15	-57.45** to 71.28** 79128A X RR55 to 68897A X RR32	-27.53* to149.44** 79128A X RR55 to 68897A X RR23	42	12	26	28	46	8	68897A × RR23 68897A × WGL 676 79156A × WGL 676 68897A × WGL 1063 79128A × RR17	44.4 26.9 33.9 33.1 32.6	149.44** 95.57** 90.45** 85.96** 83.15**
12	Hulling recovery %	-5.87** to 4.08* 68897A X WGL347 to 79128A X RR55	-6.22**TO3.15 79156A X WGL674 to 79128A X RR55	-6.99**to 2.92 78128A X RR32 to 68897A X RR65	24	30	12	42	19	35			
13	Milling recovery %	-25.11** to 22.02** 68897A X RR3 to 79156A X RR15	-29.12** to 17.16** 68897A X RR3 to 79156A X RR15	-22.94** to 8.62* 79156A X RR32 to 79156A X RR15	26	28	12	42	15	39	79156A × RR15 68897A × WGL 616	72.45 72.35	8.62** 8.47**
14	Head rice recovery (%)	-58.36** to 97.91** 79156A X RR23 to 68897A X RR15	-63.07**to63.45** 79156A X RR23 to 79128A X MTU1156	-58.79** to 57.19** 79128A X RR32 to 79156A X RR17	20	34	11	43	19	35	79156A × RR17 68897A × WGL 676 68897A × RR15 68897A × RR23 68897A × WGL 705	16.75 58.3 52 50.45 50.05	57.91** 46.48** 30.65** 26.76** 25.75**
15	Kernel	-12.93** to 24.23**	-22.32** to	-11.57** to	35	19	19	35	48	6	68897A × RR55	6.435	22.11**

	length (mm)	68897A X RR65 to 68897A X RR55	16.68** 79128A X RR32 to 68897A X RR55	20.78** 68897A X RR32 to 68897A X WGL739							68897A × WGL 739 79128A × RR50 79156A × RR50 79128A × RR55	6.365 6.167 6.165 6.14	20.78** 17.08** 16.98** 16.57**
16	Kernel Width (mm)	-9.62** to 20.26** 79156A XRR3 to 79128A X RR32	-20.42 ** to 18.73** 79156A X RR3 to 79128A X RR32	-17.04** to 1.73 79156A X RR32 to 68897A X WGL 1063	41	13	30	24	2	52	79156A × RR32 79156A × RR3 79128A × WGL 616 79128A × WGL 1810 79156A × MTU 1156	1.68 1.715 1.735 1.745 1.75	-17.04** -15.31** -14.32** 13.83** -13.58**
17	Length/Breadth ratio	-24.66** to 22.92** 79128A X RR32 to 68897A X RR55	-34.51** to 16.72** 79128A X RR32 to 68897A X WGL676	-3.65 to 30.96** 79128A X RR32 to 68897A X WGL 676	17	37	10	44	51	3	68897A × WGL 676 79128A × RR55 68897A × WGL 739 79156A × WGL 705 79156A × RR33	3.595 3.48 3.425 3.405 3.39	38.27** 33.85** 31.73** 30.96** 30.38**
18	Kernel length after cooking (mm)	-12.64** to 16.51** 79128A X RR32 to 79156AX RR55	-24.25** to9.80* 79128A X RR32 to 68897A X MTU 11-320-20	-18.38** to 44.41 79156A X RR32 to 79156A X WGL810	28	26	14	40	23	31	79156A × WGL 676 68897A × RR32 79156A × WGL 739 79156A × WGL 705	7.775 6 7.55 7.5	4.34** 11.76** 11.03** 10.29**
19	Kernel breadth after cooking (mm)	-25.23** to 22.62** 68897A X RR17 to 79156A X RR23	-26.55** to 27.50** 68897A X RR17 to 79128A X RR15	-24.55** to 0.00 68897A X RR17 to 79156A X RR32	28	26	9	45	1	53	68897A × RR17 68897A × RR32 68897A × WGL 1063 68897A × MTU 1156 68897A × MTU 11-320-20	2.075 2.1 6.55 6.4 7	24.55** -23.64** -22.73** -21.82** -20.91**
20	Kernel elongation ratio	-16.88** to14.71** 68897A x RR55 to 68897A X RR65	-18.93** to 11.43 68897A X RR55 to 68897A X RR 65	-23.94** to12.74** 68897A X RR55 to 79156A X RR3	21	33	14	40	7	47	79156A × RR3	1.13	12.74**
21	Alkali spreading value	-45.45** to 45.45** 79128 A X RR65 to 79128A X WGL1063	-50.00** to 0.00 68897A X RR23 To 79156A X WGL 347	-50.00** to 33.33** 79128A X RR65 To 79128A X RR15	19	35	8	46	6	48			
22	Volume expansion ratio	-28.74* to 254.67** 68897AX RR16 to 68897A X MTU11 -320-20	-38.46 to 202.27 ** 79156A X WGL1063 to 68897A X MTL11-320-20	-209.30** to 179.07** 68897A X MTL 11-320-20 To 68897A X WGL739	44	10	32	22	42	12	68897A × WGL 739 68897A × WGL 810 68897A × WGL 674 68897A × WGL 1063 79128A × RR15	6 5.4 5 4.15 3.25	179.07** 151.16** 132.56** 93.02** 51.16*
23	Water uptake	-38.08** to 49.36** 79156A X WGL 705 to 79156A X RR3	-42.53** to 16.78** 79156A X WGL705 to 79156A X RR3	-40.49** to 29.45** 79156A X WGL674 to 68897A X WGL810	36	18	17	37	20	34			

H1: Relative Heterosis
H2: Hetrobeltiosis
H3: Standard Heterosis

Table 4: Five best heterotic crosses for grain yield/plant along with their heterotic effects for other yield components and quality traits in Rice (*Oryza sativa*)

Crosses/ Hybrids	Relative heterosis H1	Heterobeltiosis H2	Standard hetrosis H3	Mean grain yield/ plant (gm)	Desirable significant for other traits
68897A × RR23	98.21**	38.32**	149.44**	44.4	Days to 50% flowering, PL, ET, FL,UF, GY, HRR, KW.
68897A × WGL 676	62.24**	15.23**	95.51**	34.8	Days to 50% flowering, ET, KL, GY, HRR, KW.
68897A × WGL 1063	94.13**	54.67**	85.96**	33.1	Days to 50% flowering, PL, ET, FS, TW, GY, KBAC.
79156A × WGL 676	68.24**	12.25**	90.45**	33.9	Days to 50% flowering, PL, ET, FLW, GY, KL, KW, L/B, KLAC.
79128A × R17	37.26**	-4.96**	83.15**	32.6	Days to 50% flowering, TW, UF, GY.

Conclusion

Based on the results,the desirable performance for all yield and quality traits was not expressed in a single hybrid combination. Higher magnitude of heterosis in predominant crosses over standard check were exhibited for grain yield/plant, filled seeds/panicle, test weight, days to 50% flowering, panicle length, flag leaf length, head rice recovery, length/breadth ratio, kernel breadth after cooking and volume expansion ratio, while less heterosis was expressed by hulling recovery, milling recovery, kernel length after cooking, kernel elongation ratio, water uptake, plant height, effective tillers, kernel length, kernel width and self fertility. Among the hybrids 68897A x RR23 performed well for days to 50% flowering, plant height, panicle length, effective tillers, unfilled seeds/panicle, grain yield/plant, head rice recovery, kernel width and volume expansion ratio in desired direction. The hybrids *viz*., 79156A x RR3, 79156A x RR15, 79156A x WGL347, 79128A x RR15, 68897A x RR3, 68897A x RR17, 68897A x RR50, 68897A x RR55 and 68897A x MTU11-320-11 performed well for grain yield/plant combined with several other important traits like days to 50% flowering, panicle length, effective tillering, flag leaf length, filled seeds/panicle, head rice recovery, kernel length, kernel width, length/breadth ratio and kernel breadth after cooking in desired direction. So these promising cross combinations can be further used in rice breeding programmes by tested in observational/multilocational trial before the commercial exploitation of its heterotic potential.

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