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Estimation of combining ability and gene action for yield, yield components and grain zinc content in rice (*Oryza Sativa* L.) hybrids

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Abstract
Thirty F_1 hybrids developed by crossing 6 lines with 5 pollen parents were studied along with two checks (BPT5204 and DRR dhan-45) for 16 different characters contributing to yield and grain Zn content in rice during *Kharif*-2019 at Banaras Hindu University, Varanasi in a randomized complete block design with three replications. The analysis revealed that variance due to parents *Vs.* hybrids were found highly significant for most of the characters except for days to 1st flowering, days to 50% flowering, grain L/B ratio and harvest index. All the characters except plant height exhibited highly significant variance due to line x tester. Among the lines, HUR-3022 was identified as good general combiner for number of effective tillers, spikelet fertility %, biomass, grain yield per plant, grain yield per plot and grain Zn content. Whereas among testers, Dudhkander showed good GCA effect for panicle length, grain yield per plant, grain yield per plot, biomass and a moderate combiner for grain Zn content suggesting that these parents can be exploited in hybrid breeding programs targeted for both yield and improvement in grain Zn content. Among hybrids, cross HUR-3022 x Sathi was considered good specific combiner for grain Zn content and a moderate specific combiner for grain yield per plant and grain yield per plot and also showed highest *per se* performance for grain Zn suggesting hybrid HUR-3022 x Sathi may be exploited for developing high grain Zinc hybrid in the future breeding programs. Further, grain yield per plant and grain Zn content exhibited low heritability and low genetic advance as percent mean indicating a greater influence of environment on these traits.

Keywords: general combing ability, heritability, rice hybrids, specific combining ability, grain zinc

Introduction

Rice, botanically known as *Oryza sativa* L. with 12 pairs of chromosomes belongs to the sub-tribe *Oryzeae* and family Poaceae. It has wider genetic diversity occurring in nature with 24 distinctively known species everywhere in the tropical countries, either in cultivated or wild form. Out of total 24 species, *Oryza sativa* and *Oryza glaberrima* are cultivable and others are wild. There are three subspecies of *Oryza sativa viz. indica, japonica and javanica.* Rice is the main food source for more than half of the world's population (Rao *et al*., 2020) [26]
and contains 6-12% protein, 70-80% carbohydrate, 1.2-2.0% mineral matter and significant fat and vitamin content (Eggum, 1979)[5], but the popular high yielding rice varieties that are currently cultivated are a poor source of essential micronutrients such as Zn and Fe in their polished (white) form (Kennedy *et al.*, 2002; Sharma *et al.*, 2013)[14],[28]. Also, climate change, particularly rising concentrations of atmospheric carbon dioxide, reduces the concentration of grain Zn content. Iron and Zinc micronutrient deficiencies are among the most prevalent in humans and 1/3rd of the world's population are at the risk of zinc deficiency (HarvestPlus, 2014)[10]. Bio-fortification of rice in its polished form with enhanced levels of Zn may be a cost-effective and sustainable solution to combat malnutrition in Zn. The process of enriching food grains for nutritive elements in crop plants using genetic approaches is known as Bio-fortification (Pradhan *et al*., 2020) [20]. Breeding rice varieties with high grain Zn has been suggested to be a sustainable, targeted, food-based and cost-effective approach in alleviating Zn deficiency. Given this, it is always necessary to understand the genetic nature of the parents before undertaking any crop improvement program. Combining ability analysis tends to be the fastest and most reliable method of understanding the genetic nature of different characteristics, and is a useful guide for identifying and selecting superior parents for the hybridization program (Begum *et al.*, 2020)[2]. Good general combining parents results in a higher frequency of heterotic hybrids than poorly combining parents. The combining ability of the parents provides the breeders with an insight into the nature and relative magnitude of fixable (additive) and non-fixable genetic variances (non-additive) (Cockerham, 1961; Pradhan *et al*., 2006) [4, 21]. The success of future hybrid rice programs depends upon the identification of parents having good combining ability and hybrids with a higher magnitude of heterotic combination. Therefore, combining ability along with the heritability and genetic advance was analyzed in limited germplasm set to identify appropriate parents, crosses, and breeding procedures for future breeding programs.

Materials and Methods

Plant Material and Layout

The present study was conducted during *Kharif*-2019 with experimental material consisting of 11 parental lines (six lines and five testers). The genotypes, NDR-359, HUR-1309, HUR-1304, Rajendra kasturi, Vandana and HUR-3022 acted as lines whereas the genotypes Sathi, URG-30, IR 91143 AC 293-1, IR 91143 AC 290-1 and Dudhkander are used as testers. These were crossed in a Line x Tester fashion and the corresponding 30 F_1 hybrids along with two standard checks BPT-5204 (for yield) and DRR dhan-45 (for grain Zinc) were evaluated in a randomized complete block design (RCBD) with three replications with the spacing of 20 x 15 cm at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, UP, India. All the recommended agronomic practices were followed to grow a healthy crop.

Morphological Data

Data was collected for 16 quantitative traits *viz.*, days to 1st flowering, days to 50% flowering, days to maturity, plant height, number of effective tillers per plant, panicle length, number of grains per panicle, spikelet fertility %, 1000-grain weight, grain L/B ratio, kernel L/B ratio, grain yield per plant, grain yield per plot, biomass, harvest index and grain Zn content. Data for most of the traits was collected on five randomly selected plants in each replication whereas, for days to 1st flowering, days to 50% flowering, days to maturity, grain yield per plot, biomass and harvest index the data was measured on plot basis in each replication and replication mean was further used for statistical analysis. Grain Zinc (in ppm) was analyzed at IRRI South Asia Hub, with XRF machine facility available at Harvest Plus Lab, ICRISAT, Hyderabad. The combining ability analysis was performed following the method outlined by Kempthorne (1957) [13].

Statistical Analysis

The GCA and SCA effect of ijkth observations were estimated by adopting the following model:

$$X_{ijk} = \mu + g_i + g_j + s_{ij} + e_{ijk}$$

Where, i =1, 2 …ith line, j =1, 2 …jth tester, k =Number of replications, μ =Mean, g_i=GCA effect of ith line, g_j=GCA effect of jth tester, s_{ij}=SCA effect of hybrid of ith line with jth tester, e_{ijk} =Error effect associated with the ijkth observation

Heritability is the proportion of variation that is inherited and expressed in percentage. In a narrow sense (h^2), it is estimated with the following formula:

$$\frac{\text{Additive variance}}{\text{Phenotypic variance}} * 100$$

The classification of narrow sense heritability as given by Searle (1965) [27].

Table 1

Classification	Heritability
Low	< 40%
Moderate	41 – 50%
High	> 50%

Genetic advance is the improvement in the mean genotypic value of the selected plants over the parental population and was calculated based on the formula given by Lush (1940) [17] and Johnson *et al.* (1955) [12] as follows and is expressed as percent of mean.

Expected genetic advance (GA) = K x σ_p x h^2

Where K = Selection differential at 5% selection intensity (2.06)

σ_p = Phenotypic standard deviation

h^2 = Heritability

The classification of genetic advance is as follows:

Table 2

Genetic advance (percent)	Rate
<10	Low
10-20	Medium
>20	High

Results and Discussion

The analysis of variance for combining ability of all the traits under study has been presented in Table 1. The variance due to treatments, parents, and hybrids were highly significant for all the characters under study. The variance due to parents *vs.* hybrids was also found highly significant for most of the characters except for days to 1st flowering, days to 50% flowering, grain L/B ratio and harvest index. The variance due to lines and testers was found highly significant for all characters under study. All the characters except plant height exhibited highly significant variance due to line x tester indicating sufficient diversity among the parents and the importance of both additive and nonadditive gene effects in the inheritance of measured traits suggesting the presence of sufficient variability in the material used for the study. Similar findings were earlier reported by Bagheri *et al.* (2010) [1], Sanghera *et al.* (2012) [25], Lingaih *et al.* (2018) [16], Begum *et al*. (2020) [2] and Suvi *et al.* (2021) [31]. Combining ability analysis revealed that both GCA and SCA variances were vital for the inheritance of various traits studied. It further suggests the importance of additive and non-additive types of gene actions. In the present study, SCA variances were higher than the GCA variances for all the characters. All the characters exhibited greater SCA variance than GCA variance which revealed the prevalence of non-additive gene action involved in the inheritance of these traits. Therefore, heterosis breeding program will be more useful for the improvement of these traits. Similar finding of SCA variance greater than GCA variance have been reported by Narasimman *et al.* (2007) [18], Wang *et al.* (2009) [32], El-Rewainy *et al.* (2011) [6], Ghara *et al.* (2012) [7], Saidaiah *et al*. (2010) [24], Latha *et al.* (2013)[15], Bhadru *et al.* (2013)[3], Ghosh *et al.* (2013) [8], Hasan *et al.* (2013) [11], Lingaih *et al.* (2018) [16], Begum *et al.* (2020) [2], Gramaje *et al.* (2020) [9] and Yadav *et al.* (2021)[33].

Combining ability analysis showed that none of the parents was a good general combiner for all the characters. The GCA effects of eleven parents with their heritability and genetic advance as percent of mean are presented in Table 2. Among parents, HUR-3022 was identified as a good general combiner for number of effective tillers, spikelet fertility %, biomass, yield per plant, yield per plot, and grain Zn content whereas among testers, Dudhkander showed good GCA effect for panicle length, grain yield per plant, grain yield per plot, biomass and a moderate combiner for grain Zn content suggesting that these parents can be used in the hybrid breeding program. The GCA and SCA effects of parents and hybrids in a positive direction were considered desirable in breeding for grain yield attributes. Similar findings of positive GCA of parents and SCA of hybrids was earlier reported by Pradhan *et al.* (2006) [21], Sanghera *et al.* (2013) [25], Sahu *et al*. (2013) [23] and Yuga *et al.* (2018) [34].

Table 3: Analysis of variance for combining ability for different characters in Rice (*Oryza sativa* L.)

Source of variation	Df	Days to 1st flowering	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of effective tillers	Panicle length (cm)	No. of grains per panicle	Spikelet fertility %	1000-grain weight (g)	Grain L/ B ratio	Kernel L/B ratio	Yield per plant (g)	Yield per plot (g)	Biomass	Harvest index	Zn content (ppm)
Replicates	2	45.975 **	7.35	2.67	21.03	6.74 **	1.70	78.66	9.19	0.38	0.09	0.060 **	3.46	6995.37	19.54	0.00	1.28
Lines	5	304.312 *	177.01	115.94	757.47	18.20	50.839 **	2286.01	377.72	54.28**	2.658 **	1.336 *	55.89	113181.10	286.76	0.003 *	45.91
Testers	4	170.62	107.70	75.11	446.23	34.38 *	25.97	2702.95	1067.77	79.269 **	3.682 **	2.19 **	76.90	155726.50	553.55	0.00	85.14
Line * Tester	20	85.63**	68.574 **	65.26**	350.99**	9.63 **	9.512 **	1162.46**	499.76**	12.56 **	0.61**	0.36**	144.4 **	292563.2 **	1059.21**	0.001 **	61.937 **
Error	58	8.38	4.40	6.13	15.12	1.04	1.34	131.07	8.84	0.62	0.04	0.01	1.71	3456.07	11.16	0.00	2.03
Component of variance																	
σ^2 Line		19.82*	11.47	7.34	49.61	1.15	3.3046**	146.02	24.74	3.58 **	0.17 **	0.09*	3.58	7258.25	18.34	0.0002*	2.96
σ^2 Tester		9.09	5.71	3.85	24.05	1.8540*	1.37	144.85	58.96	4.377**	0.21**	0.12**	4.15	8412.18	30.11	0.00	4.65
σ^2_{GCA}		13.96**	8.33 **	5.439 *	35.66 *	1.53**	2.25**	145.38**	43.405 *	4.02**	0.19 **	0.106**	3.90	7887.67	24.76	0.0001**	3.88
σ^2_{sca}		26.198**	21.218**	19.83**	112.55 **	2.87**	2.275**	355.58 **	164.39 **	4.0304 **	0.1938 **	0.118**	47.45**	96085.28**	349.186**	0.0002**	20.15**
σ^2_{GCA} / σ^2_{sca}		0.53	0.39	0.27	0.32	0.53	0.97	0.41	0.26	1.00	0.92	0.90	0,063	0.08	0.08	0.50	0.19
Heritability (Narrow Sense) %		49.46	42.16	33.34	37.88	48.84	58.67	42.87	34.26	65.72	65.04	63.75	13.92	13.92	12.30	40.79	27.32
Genetic Advance as per cent of mean 5 %		7.66	5.46	3.92	10.71	2.52	3.35	23.00	11.23	4.73	1.02	0.76	2.15	6.55	5.08	0.02	3.00

*, ** significant at 5 percent and 1 percent levels of probability respectively; df = Degree of freedom; GCA = general combining ability; SCA = Specific combining abilit

Among the lines, HUR-3022, NDR-359 and among testers, IR 91143 AC290-1 and IR 91143 AC 293-1 are considered to be the good general combiners for yield and grain Zn content among lines, HUR-3022, Vandana and Sathi are good general combiners. High SCA effect (Table 3) is mostly from dominance and interaction effects that existed between the parents used in hybridization. In the present study, positive significant-high SCA effects for grain yield per plant were exhibited by hybrids, Rajendra kasturi x IR 91143 AC 290-1, Vandana x URG-30 and HUR-1309 x Dudhkander and can be called as good specific combiners. Whereas, hybrids HUR-3022 x Sathi, NDR-359 x Dudhkander and Rajendra kasturi x URG-30 are good specific combiners for grain Zinc content. Among hybrids, cross HUR-3022 x Sathi is considered a good specific combiner for grain Zn and a moderate specific combiner for grain yield per plant and grain yield per plot. It also exhibited the highest positive standard heterosis over checks BPT-5204 and DRR dhan-45 and showed the highest mean performance for grain Zn. The results suggest that the hybrid, HUR-3022 x Sathi can be exploited for developing high grain Zinc hybrid in future breeding programs as reported by Rashid *et al.* (2007) [22], Sundaram *et al.* (2019) [30] and Yadav *et al.* (2021) [33].

Table 4: Estimates of general combining ability (GCA) effects of the parents for various characters in rice (*Oryza sativa* L.)

Parents	Days to 1st Flowering	Days to 50% Flowering	Days to maturity	Plant height (cm)	No. of effective tillers	Panicle length (cm)	No. of Grains per panicle	Spikelet fertility %	1000-grain weight(g)	Grain L/B Ratio	Kernel L/B Ratio	Yield per plant (g)	Yield per Plot (g)	Biomass	Harvest Index	Zn Content (ppm)
Lines																
NDR-359	0.250	1.089	-0.461	-0.266	0.400	1.406 **	0.057	-0.005	2.983 **	-0.152**	-0.135 **	0.607	27.333	-1.058	0.021 **	-1.550 **
HUR-1309	-0.483	-0.644	-0.128	0.656	0.044	2.327 **	8.669 **	-4.117 **	1.296 **	0.802**	0.541 **	-0.493	-22.168	-1.764 *	0.006	-1.784 **
HUR-1304	0.283	-0.778	1.372 *	-13.419 **	-1.622 **	-0.047	-13.120 **	4.021 **	-1.644 **	-0.165**	-0.064 **	-1.193 **	-53.668 **	-1.720	-0.016 **	-1.154 **
Rajendra kasturi	6.883 **	5.722 **	4.606 **	6.549 **	-0.400	-0.509	14.263 **	-7.495 **	-2.077 **	-0.055	-0.061 *	0.240	10.788	1.665	0.005	0.853 **
Vandana	-7.317 **	-4.878 **	-3.328 **	5.243 **	-0.178	-3.046 **	-16.393 **	1.827 **	-0.694 **	-0.435**	-0.349 **	-2.426 **	-109.168 **	-4.944 **	-0.017 **	1.090 **
HUR-3022	0.383	-0.511	-2.061 **	1.237	1.756 **	-0.131	6.524 *	5.769 **	0.136	0.006	0.068 **	3.264 **	146.883 **	7.822 **	0.001	2.544 **
S.E ±	0.6846	0.5727	0.6202	0.9427	0.2592	0.2910	2.5261	0.6617	0.1797	0.0461	0.0237	0.3766	16.9457	0.8814	0.0039	0.3150
Testers																

Sathi	-2.572 **	-2.233 **	-0.850	1.624	1.663 **	-1.621 **	-18.328 **	-11.994 **	1.736 **	0.423 **	0.343 **	-3.162 **	-142.293 **	-8.599 **	0.012 **	1.136 **
URG-30	-3.794 **	-2.567 **	-2.461 **	-3.343 **	0.867 **	-0.618 *	-3.031	-0.015	-3.032 **	-0.591 **	-0.512 **	-0.579	-26.068	-1.571	-0.002	-2.152 **
IR 91143 AC 293-1	2.594 **	1.350 *	1.400 *	-3.020 **	-1.244 **	-0.009	-0.545	5.142 **	0.733 **	0.029	-0.053 *	0.102	4.570	0.687	-0.003	2.170 **
IR 91143 AC 290-1	3.122 **	3.239 **	2.706 **	-3.331 **	-1.578 **	0.783 **	13.723 **	8.092 **	-1.253 **	0.443 **	0.310 **	1.574 **	70.833 **	3.974 **	-0.002	-2.529 **
Dudhkander	0.650	0.211	-0.794	8.070 **	0.293	1.465 **	8.181 **	-1.225 *	1.817 **	-0.304 **	-0.089 **	2.066 **	92.958 **	5.509 **	-0.006	1.375 **
S.E ±	0.6249	0.5228	0.5662	0.8606	0.2367	0.2656	2.3060	0.6041	0.1640	0.0421	0.0216	0.3438	15.4692	0.8046	0.0035	0.2876

*, ** Significance at 5 per cent and 1 per cent levels of probability respectively

Table 5: Estimates of specific combining ability of 30 crosses for various characters in Rice (*Oryza sativa* L.)

Crosses	Days To 1st Flowering	Days to 50% Flowering	Days to Maturity	Plant Height (cm)	No. of effective Tillers	Panicle Length (cm)	No. of Grains per Panicle	Spikelet Fertility %	1000-Grain Weight (g)	Grain L/B Ratio	Kernel L/B Ratio	Yield per Plant (g)	Yield per Plot (g)	Biomass	Harvest Index	Zn Content (ppm)
NDR359 x Sathi	-8.028 **	-7.033 **	-7.15 **	-4.791 *	1.470 *	-1.336 *	-19.428 **	-17.953 **	-1.723 **	-0.043	0.067	-3.038 **	-136.708 **	-7.082 **	-0.011	-7.550 **
NDR359 x URG-30	0.528	0.633	0.794	3.688	-0.956	-0.184	19.554 **	0.095	1.051 *	0.311 **	0.224 **	1.713 *	77.068 *	3.387	0.010	4.039 **
NDR359 x IR 91143 AC 293-1	6.472 **	4.383 **	1.600	0.976	-0.956	0.301	-0.377	8.923 **	-1.620 **	-0.100	-0.056	5.865 **	263.930 **	16.673 **	-0.015	-3.916 **
NDR359 x IR 91143 AC 290-1	7.278 **	5.494 **	6.294 **	-5.037 *	0.267	0.540	11.521 *	5.895 **	1.943 **	-0.286 **	-0.200 **	-0.441	-19.833	-2.365	0.011	1.582 *
NDR359 x Dudhkander	-6.250 **	-3.478 **	-1.539	5.164 *	0.174	0.679	-11.270	3.040 *	0.349	0.118	-0.035	-4.099 **	-184.458 **	-10.613 **	0.005	5.845 **
HUR-1309 x Sathi	-0.294	1.700	1.850	-0.457	-0.619	-0.200	-8.594	-17.817 **	-3.046 **	-0.204	-0.155 **	-6.271 **	-282.208 **	-17.989 **	0.025 **	-0.650
HUR-1309 x URG-30	-1.406	-1.300	-0.206	3.700	0.956	0.518	12.554 *	0.527	2.355 **	-0.511 **	-0.238 **	3.813 **	171.568 **	8.089 **	0.011	0.372
HUR-1309 x IR 91143 AC 293-1	2.872	0.783	-2.067	-11.012 **	0.956	-0.658	6.734	12.212 **	2.050 **	0.338 **	0.076	-3.035 **	-136.570 **	-7.065 **	-0.016	4.584 **
HUR-1309 x IR 91143 AC 290-1	1.678	-0.772	-1.372	9.219 **	0.844	0.861	-9.145	-2.510	-1.127 **	-0.054	-0.128 *	10.493 **	472.168 **	29.458 **	-0.014	-3.151 **
HUR-1309 x Dudhkander	-2.850	-0.411	1.794	-1.450	-2.14 **	-0.521	-1.548	7.588 **	-0.234	0.431 **	0.444 **	-4.999 **	-224.958 **	-12.493 **	-0.006	-1.155
HUR-1304 x Sathi	-3.061	-3.167 *	-0.317	18.568 **	2.048 **	3.011 **	7.806	14.678 **	0.497	-0.149	-0.301 **	0.929	41.793	3.346	-0.021 *	0.587
HUR-1304 x URG-30	3.828 *	3.167 *	1.628	-7.547 **	-2.489 **	0.491	-16.602 **	-1.508	1.678 **	0.197	0.077	-0.654	-29.433	-1.802	0.003	3.776 **
HUR-1304 x IR 91143 AC 293-1	-5.394 **	-3.750 **	-2.400	7.671 **	2.289 **	0.641	-14.532 *	-4.561 **	-0.294	-0.089	-0.144 **	-1.835 *	-82.570 *	-4.999 *	-0.001	-0.496
HUR-1304 x IR 91143 AC 290-1	-2.089	-1.972	-1.872	3.507	-0.267	0.713	16.810 **	-6.672 **	1.263 **	0.081	0.144 **	-4.474 **	-201.333 **	-12.263 **	0.007	-2.381 **
HUR-1304 x Dudhkander	6.717 **	5.722 **	2.961 *	-22.200 **	-1.581 **	-4.856 **	6.519	-1.938	-3.144 **	-0.039	0.224 **	6.034 **	271.543 **	15.719 **	0.012	-1.485 *
Rajendra kasturi x Sathi	4.339 **	5.667 **	4.783 **	-12.217 **	-3.285 **	-0.464	-27.800 **	-14.214 **	4.537 **	0.367 **	0.434 **	-9.087 **	-408.913 **	-26.622 **	0.037 **	-3.486 **
Rajendra kasturi x URG-30	0.561	-1.000	-0.272	11.129 **	1.289 *	-0.158	14.959 *	7.868 **	-2.755 **	-0.636 **	-0.454 **	7.160 **	322.213 **	22.173 **	-0.030 **	4.769 **
Rajendra kasturi x IR 91143 AC 293-1	-3.328 *	-1.417	-0.800	1.617	1.511 *	-1.421 *	-16.555 **	-14.320 **	-0.490	-0.248 *	-0.042	-2.936 **	-132.100 **	-7.996 **	0.011	-2.036 **
Rajendra kasturi x IR 91143 AC 290-1	-1.022	-3.139 *	-1.106	0.439	-0.711	-0.115	21.649 **	9.936 **	-1.624 **	1.121 **	0.750 **	3.094 **	139.213 **	6.715 **	-0.002	3.412 **
Rajendra kasturi x Dudhkander	-0.550	-0.111	-2.606	-0.968	1.196 *	2.158 **	7.746	10.729 **	0.333	-0.604 **	-0.689 **	1.769 *	79.587 *	5.730 **	-0.016	-2.659 **

Vandana x Sathi	-1.461	-4.067 **	-5.283 **	-13.111 **	-0.507	-2.617 **	20.800 **	16.475 **	-0.063	-0.141	-0.024	10.329 **	464.793 **	28.087 **	-0.011	4.210 **
Vandana x URG-30	4.761 **	7.267 **	6.994 **	-1.576	-0.489	0.296	-3.663	9.299 **	-0.748	0.481 **	0.293 **	-5.921 **	-266.433 **	-16.608 **	0.009	-8.501 **
Vandana x IR 91143 AC 293-1	0.039	1.017	2.467	5.766 **	-0.822	1.271	11.129	-3.803 *	-0.030	-0.141	-0.009	5.732 **	257.930 **	15.118 **	0.004	3.310 **
Vandana x IR 91143 AC 290-1	-1.322	0.294	1.494	2.244	0.733	-0.314	-11.779 *	-2.780	-0.285	-0.554 **	-0.451 **	-1.907 *	-85.833 *	-5.161 *	0.006	-0.058
Vandana x Dudhkander	-2.017	-4.511 **	-5.672 **	6.677 **	1.085	1.364 *	-16.487 **	-19.190 **	1.126 **	0.355 **	0.191 **	-8.232 **	-370.458 **	-21.437 **	-0.008	1.038
HUR-3022 x Sathi	8.506 **	6.900 **	6.117 **	12.006 **	0.893	1.606 *	27.217 **	18.830 **	-0.202	0.170	-0.020	7.139 **	321.243 **	20.261 **	-0.019 *	6.889 **
HUR-3022 x URG-30	-8.272 **	-8.767 **	-8.939 **	-9.393 **	1.689 **	-0.964	-26.802 **	-16.281 **	-1.581 **	0.159	0.098	-6.111 **	-274.983 **	-15.240 **	-0.003	-4.456 **
HUR-3022 x IR 91143 AC 293-1	-0.661	-1.017	1.200	-5.017 *	-2.978 **	-0.133	13.601 *	1.550	0.384	0.240 *	0.175 **	-3.792 **	-170.620 **	-11.731 **	0.017	-1.444 *
HUR-3022 x IR 91143 AC 290-1	-4.522 **	0.094	-3.439 *	-10.373 **	-0.867	-1.685 *	-29.056 **	-3.869 *	-0.170	-0.308 **	-0.117 *	-6.764 **	-304.383 **	-16.385 **	-0.008	0.594
HUR-3022 x Dudhkander	4.950 **	2.789 *	5.061 **	12.777 **	1.263 *	1.176	15.041 *	-0.229	1.570 **	-0.261 *	-0.136 *	9.528 **	428.743 **	23.094 **	0.014	-1.583 *

*, ** Significance at 5 per cent and 1 per cent levels of probability respectively

Moderate heritability (Table 1) coupled with low genetic advance as percent of mean was observed for various characters *viz.* days to first flowering, days to 50% flowering, the number of effective tillers, panicle length and low heritability coupled with low genetic advance was observed for days to maturity, plant height, spikelet fertility percentage, grain yield per plant, grain yield per plot, biomass, harvest index and grain Zn content. From this study grain yield per plant and grain Zn content exhibited low heritability and low genetic advance, showing that these traits are more influenced by the environmental conditions. These findings are in line with Pandey *et al.* (2020) [19] for grain Zinc content.

Conclusion

Based on overall performance, line HUR-3022 and tester Dudhkander were identified to be good general combiners for most of the traits. However, the cross, HUR-3022 x Sathi is considered a good specific combiner for Zn and a moderate specific combiner for yield per plant and yield per plot and can be exploited for developing high grain Zinc hybrid in the future breeding programs after evaluation under multiple locations. Most of the economic traits showed low heritability as these traits are influenced by environmental conditions and governed by multiple genes.

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