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Development of Zinc Enriched Hybrid Rice Utilizing Cytoplasmic Male Sterile (CMS) System

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ABSTRACT: The intended effect of the study was to discern the genetics of grain zinc in rice by hybridization, assess the amounts of Zinc (Zn) and Iron (Fe) in the parents and hybrids, and determine the genetic variability and character associations of twenty characters of hybrids. The mean performance for Zn concentration in the parent and hybrids at the brown condition was better for IR62A and Gan46A x KataribhoghR than the other twenty quantitative traits, respectively. Thousand grain weight showed high estimates of phenotypic coefficient of variation (PCV) was (54.380%) and genotypic coefficient of variation (GCV) was (54.546%), which were followed by Zn content (42.666 & 43.956 %) and straw yield (49.371 & 50.078 %). According to the study's findings, pollen fertility (%) (99.96) and grain yield (t/ha) (99.365) expressed high heritability coupled with high genetic advance. In hybrids, a highly significant and positive correlation was observed for grain yield per plant with filled seed (0.331*), unfilled seed (0.202*), grain length (0.242**), harvest index (0.256*), Zn content (0.244**), Fe content (0.224**), and thousand seed weight (0.191**). The highest positive direct contribution to grain yield/plant at the genotypic level was expressed by thousand seed weight, followed by straw yield/plant (g), and days to 50% flowering through path coefficient analysis. The highest correlations existing between different plant traits can be used to conduct indirect selection of a desired trait in a breeding program.

Keywords: Cytoplasmic Male Sterility, Heritability, Hybrid, Path coefficients, Rice.

I. INTRODUCTION

Rice (*Oryza sativa L.*) is the most important cereal crop and primary energy source for two thirds of the world's population [1]. Bangladesh is an agrarian country and its staple food is rice. About 76% of the people live in rural areas, and 47.5% of the total manpower is involved in agriculture [2]. Bangladesh is the fourth-largest producer and consumer of rice in the world, with an annual production ranging from 52 to 53 million tons [3]. A modest estimate suggests that the demand for rice in Bangladesh will increase by over 80% in the next 20 years to feed the growing population [4]. Both the poor and rich in this world consume rice in one form or another.

In the last two decades, new research findings generated by nutritionists have brought to light the importance of micronutrients, vitamins, and proteins in maintaining good health, adequate growth, and even acceptable levels of cognition [5]. In Bangladesh, Micronutrient malnutrition affects 86.9% 6-59 months children and 94.6% Non-Pregnant Non-Lactating women (NPNL), whereas Zn and Fe deficiency are 31% and 15.1% in 6-59 months children and 43.4% and 14.1% in NPNL women [6]. Zn and Fe deficiencies are the most widespread human micronutrient deficiencies and are particularly prevalent in resource-poor countries where there is a heavy dietary reliance on staple crops. As staple foods are eaten in large quantities every day by malnourished poor, the addition of even small quantities of micronutrients is beneficial.

The role of Zn as an essential micronutrient that possesses direct antiviral properties (e.g., influenza) is also critical in generating both innate and acquired (humoral) antiviral responses [7]. Importantly, Zn deficiency results in a compromised immune system, as evidenced by thymic atrophy, lymphopenia, and defective lymphocyte responses in animal studies [8]. In similar fashion, severe acute respiratory syndrome (SARS) coronavirus RdRp template binding and elongation were inhibited by Zn [9].

Males aged 15 to 74 years need about 12 to 15 mg of Zn daily, while females aged 12 to 74 years need about 68 mg of Zn daily [10]. In developing countries, Zn deficiency is the fifth-leading cause of the loss of healthy life years. In industrial countries, mainly the elderly population is affected by Zn deficiency [11]. Zn deficiency has been known for 50 years [12] and is associated with skin abnormalities, hypogonadism, cognitive impairment, growth retardation, and imbalanced immune reactions that favor allergies and autoimmune diseases [13]. Zn is one of the essential micronutrients and serves as a co-factor for more than 300 enzymes involved in the metabolism of carbohydrates, lipids, proteins, and nucleic acids [14].

Biofortification is the process by which the nutritional quality of food crops is improved through agronomic practices, conventional plant breeding, or modern biotechnology. Biofortification of staple food crops for enhanced micronutrient content through genetic manipulation is the best option available to alleviate hidden hunger with little recurring cost [15]. In rice, it is possible to combine the high micronutrient density trait with a high yield economically through biofortification. Biofortification of rice with Zn and Fe is a cost-effective and sustainable solution to mitigate Zn and Fe deficiency problems in rice-consuming, malnourished Asian populations.

Breeding and adoption of rice cultivars with enhanced grain Zn content along with high yield potential has become a priority for breeders. The development and use of hybrid rice varieties on a commercial scale utilizing male sterility and fertility restoration systems has proved to be one of the most important milestones in the history of rice improvement. The initial breeding strategy to produce hybrids relied on three breeding lines known as the A, B, and R lines. A line is the cytoplasmic male sterile line, where the male sterility is jointly controlled by the recessive nuclear gene and the sterile cytoplasm. The B line is an isogenic line of the A line, with only a difference in male sterility and fertility, and the R line possesses a fertility restoration gene [16].

Nevertheless, the goal of the current study is to make experimental hybrids through hybridization of A and R lines with high Zn and Fe contents. Moreover, selection is of fundamental importance to improving a crop. Consequently, variability, character association, its causal effect on yield, and its contributing characters need to be known for efficient selection. In order to evaluate the genetic variability and character association of 20 quantitative characters of rice hybrids, the study was performed with the aim of determining the grain Zn and Fe content in the parents as well as their hybrids.

II. MATERIALS AND METHODS

The experiment was carried out during Aman season 2017–2018 at the research field and laboratory of the Department of Genetics and Plant Breeding, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur. The experiment was laid out in a randomized complete block design (RCBD) with three replications in the field. The 10 parents (Table 1), along with 25 crossed seeds, were evaluated. At first, seeds of each genotype were sown in the pot at the laboratory, and then transplanted to the main field with a spacing of 30 cm between rows and 20 cm between the plants within the row. Nitrogen was provided in the form of urea at basal, 30, and 60 days after sowing at 50%, 25%, and 25%, respectively. Phosphorus was provided as a single super phosphate (16% P_2O_5) and potassium as murite of potash (60% K_2O). Irrigation was done once every five days for all the plots. All necessary measures were taken to control pest and disease infestations. All the observations were recorded on five randomly selected plants for quantitative characters, viz., days to first flowering, days to fifty percent flowering, days to maturity, pollen fertility, plant height (cm), number of productive tillers per hill, panicle length (cm), number of tillers, straw yield, test weight (g), grain length (mm), grain breadth (mm), biomass, harvest index, Zn content (ppm), Fe content (ppm), grain yield ton per hectare. The analysis of Fe and Zn content (ppm) of grain was done at brown condition using the XRF (X-Ray Fluorescence Spectrometry) method in Harvest Plus Laboratory, Bogura. XRF is a non-destructive analytical technique used to determine the elemental composition of materials. The statistical analysis of the data on individual characters was performed using PB Tools (mean performance) and the OPSTAT statistical package. Statistical methods like estimates of genotypic and phenotypic co-efficient of variation were made as suggested by Falconer (1960) [17]; for calculating the genotypic and phenotypic correlation coefficient for all possible combinations, the formula suggested by Johnson et al. (1955) and Hanson et al. (1956) were used[18], [19], and the correlation coefficient was further partitioned into components of direct and indirect effects by path coefficient analysis following the methods as originally described by Wright (1921) and later described by Dewey and Lu (1959) [20], [21].

Table 1: List of Experimental Materials

SL. No.	A line	SL. No.	R line
A_1	IR58A	R1	Hera5R
A_2	IR62A	R2	BU7R
A_3	IR68A	R3	ACI1R
A_4	Gan46A	R4	BHD1R
A_5	BRRI1A	R5	KataribhoghR

III. RESULTS AND DISCUSSION

3.1 Evaluation of grain Zinc and phenotypic characters in the parents and hybrids

3.1.1 Mean performance of parents and hybrids

Table 2 illustrates the average of 20 quantitative traits in parents and hybrids. At a 1% level of significance, each attribute is significant among genotypes. Parents' first flowering periods ranged from 40 (BRRI1A) to 68 (KataribhogR) days, with an average of 54 days. Compared to KataribhogR, BRRI1A was the earlier to bloom. For hybrids, a direct cross took 45 days to reach first flowering. In this instance, the BRRI1A x BHD1R hybrid was flowering earlier than other hybrids. The hybrid Gan46A x BU7R required the fewest days to reach 50% flowering (49), and statistically, it was comparable to BRRI1A x KataribhogR. The duration that it took IR62A x BU7R, in contrast, to reach 50% flower (61) was significantly longer than that of the other hybrids. For days to 50% flowering, parents expressed a wide range (55–77 days), with an average of 66 days. The mean of hybrids and parents was 56 days, and the heritability was 0.98 for 50% flowering.

With an average of 65%, pollen fertility ranged from 0 to 99% (R2). In hybrids, IR58AxHera5R had the highest pollen fertility (95%), which was comparable to IR68A x BU7R and IR68A x BHD1R, which were followed by IR58A x BU7R, Gan46A x BU7R, IR58A x BHD1R, and Gan46A x ACI1R. Parents showed a wide range (75–97 days) for the number of days before maturity. IR62A took the fewest days (75) to mature, while KataribhogR took the most days (97) to mature. BRRI1A x BU7R and Gan46A x BU7R were early matured compared to IR58A×BHD1R and IR62A×BHD1R. The typical maturity period lasted 84 days (Table 2).

The combination of IR68A and KataribhogR generated the shortest plant among the lines. The tallest plant appeared to be the Gan46A x KataribhogR. The plant heights varied from 80.67 cm (IR68A x KataribhogR) to 156.67 cm (KataribhogR), with an average of 103.42 cm across the lines. Between lines, the average number of productive tillers per hill varied greatly. The most productive tillers per hill were the 17.00 (BRRI1A x BHD1R) tillers, followed by the 15 (IR68A x KataribhogR), the 14.67 (IR68A x ACI1R), and the 14.33 (BRRI1A x ACI1R), all of which were significantly greater than the mean (13.21). Total number of tillers ranged from 11.67 IR58A to 33 in KataribhogR, with an average of 22. In hybrids, IR62A x BHD1R had the most tillers overall (17), followed by IR58A x KataribhogR, IR68A x KataribhogR, and IR62A x BHD1R. Straw yield difference among the parents ranged from 10g (IR58A) to 40g (KataribhogR), with an average of 21g. The range of hybrid straw yields was 6.67g for IR62A x BU7R to 40g for IR62A x BHD1R (Table 2).

Table 2: Mean Performance of Parents and Hybrids of rice

Genotype	DFF	50% Flowering	PF (%)	DM	PH	NPT	PL	Tiller	SY(g)	FS	UFS
IR58AxHera5R	51	54	95	84	106.00	11.00	25.00	11.00	20.00	152	47
IR62A×Hera5R	53	56	30	84	94.00	9.67	24.67	10.00	13.33	138	50
IR68A×Hera5R	51	54	80	84	98.33	8.67	25.50	9.00	6.67	146	17
BRRI1A x Hera5R	49	54	80	84	98.00	7.67	25.50	7.67	13.33	125	28
Gan46A x Hera5R	49	53	80	84	114.67	11.33	26.83	11.33	20.00	192	22
IR58 A×BU7R	51	54	90	84	103.00	11.33	25.17	11.67	20.00	143	52
IR62A×BU7R	60	61	70	85	95.00	10.00	22.17	10.00	6.67	109	56
IR68A x BU7R	55	56	92	84	99.33	7.67	24.33	8.00	13.33	134	64
BRRI1A x BU7R	45	50	80	82	100.00	11.67	24.00	9.67	13.33	192	17
Gan46A x BU7R	45	49	90	82	109.33	9.67	24.00	9.67	13.33	192	17
IR58A×ACI1R	56	58	70	84	97.33	10.33	25.00	10.67	26.67	138	47
IR62A×ACI1R	52	54	70	84	92.67	9.67	23.83	10.33	26.67	128	36
IR68A x ACI1R	47	50	75	84	100.00	14.67	25.50	15.00	6.67	161	48
BRRI1A x ACI1R	50	54	60	84	100.00	14.33	26.17	14.67	26.67	142	16
Gan46A x ACI1R	47	53	90	84	104.33	13.00	27.17	13.00	26.67	163	36
IR58A×BHD1R	56	59	90	87	103.67	13.67	26.33	13.67	40.00	130	78
IR62A×BHD1R	56	59	75	87	101.67	9.67	24.00	9.67	40.00	77	72
IR68A x BHD1R	59	59	92	84	100.67	7.00	25.50	7.33	6.67	107	33
BRRI1A x BHD1R	47	50	85	84	100.00	17.00	25.00	17.00	13.33	128	9
Gan46A x BHD1R	51	54	80	84	102.33	13.33	23.50	13.67	13.33	124	35
IR58A×KataribhogR	49	53	15	84	115.00	13.00	24.83	14.00	20.00	143	44
IR62A×KataribhogR	53	56	15	84	115.50	5.33	23.00	5.67	6.67	47	66
IR68A x KataribhogR	45	50	75	84	80.67	15.00	22.83	16.33	20.00	99	29
BRRI1A x KataribhogR	45	49	80	84	115.00	9.00	24.33	12.00	13.33	123	25
Gan46A x KataribhogR	47	51	60	84	126.67	12.67	24.83	13.67	26.67	144	41
IR58A	47	55	0	76	87.33	16.00	26.83	15.67	14.00	33	117
IR62A	47	55	0	75	83.67	19.33	24.43	19.33	13.33	14	131
IR 68888A	47	55	0	77	84.33	20.33	27.00	20.33	20.33	2	129
Gan46A	58	67	0	88	81.33	18.67	24.50	18.67	20.00	31	201
BRRI1A	40	59	0	82	80.67	23.33	24.27	23.33	13.67	5	131
Hera5R	49	59	93	82	108.50	13.67	23.00	13.67	20.00	111	10
BU7R	50	58	99	81	111.00	12.67	24.83	12.67	20.00	138	22
KataribhogR	68	77	76	97	156.67	33.67	27.03	33.67	40.00	128	19
BHD1R	61	71	92	88	134.67	14.33	26.83	14.33	33.33	141	22
ACI1R	50	59	97	83	118.20	14.00	26.20	14.00	26.67	127	5
Mean	51	56	65	84	103.42	13.21	15.42	22.99	19.28	117.25	50.70
LSD (0.05)	1.44	1.96	0.59	0.91	17.14	5.40	3.90	4.29	2.59	53.45	19.11
SED	0.73	1.00	0.30	0.46	8.74	2.75	1.99	2.19	1.32	27.27	9.75
Heritability in broad sense(H)	0.99	0.98	0.99	0.99	0.84	0.87	0.88	0.96	0.99	0.60	0.88
Level of significance	**	**	**	**	**	**	**	**	**	**	**

** indicate significance at 1% levels.

Legend: DFF=Days to first flowering, 50%F=Days to Fifty Percent Flowering, DM=Days to Maturity, PF=Pollen Fertility, PH=Plant Height (cm), NPT=Number of Productive Tillers per hill, PL=Panicle Length (cm), SY= Straw Yield, FS= Filled Spikelet, UFS= Unfilled Spikelet, TSW=Thousand Seed Weight(g), SL=Seed Length (mm), SB=Seed Breadth(mm), BM=Biomass, HI=Harvest Index, Zn=Zinc Content (ppm), Fe=Iron Content (ppm), YL (g/plt)= Grain Yield gram per plant, YL(t/ha)=Grain Yield ton per hectare.

Table 2: Continued

Genotype	SL(mm)	SB(mm)	TSW(g)	YL(g/Plt)	YL (tn/ha)	BM (g/plt)	HI (%)	Zn (ppm)	Fe (ppm)
IR58AxHera5R	9.63	2.33	24.67	22.853	7.542	42.85	53.30	30.83	11.90
IR62A×Hera5R	10.03	2.33	24.60	19.117	6.309	32.45	59.24	30.70	11.73
IR68A×Hera5R	10.00	2.57	24.80	17.063	5.631	23.73	72.08	28.43	12.27
BRRI1A x Hera5R	8.20	2.77	23.40	14.147	4.668	27.48	51.62	13.82	4.46
Gan46A x Hera5R	10.43	2.77	25.13	42.727	14.100	62.73	68.11	29.30	13.03
IR58 A×BU7R	9.93	2.60	22.93	29.113	9.607	49.11	59.34	27.20	10.93
IR62A×BU7R	8.67	2.57	22.47	2.887	0.953	9.55	30.54	19.28	6.32
IR68A x BU7R	9.57	2.47	23.60	19.553	6.453	32.89	59.47	27.17	12.03
BRRI1A x BU7R	8.23	2.60	23.80	26.380	8.705	39.71	66.69	31.40	13.93
Gan46A x BU7R	8.53	2.93	25.13	14.860	4.904	28.19	52.65	28.70	17.57
IR58A×ACI1R	10.53	2.53	20.00	35.980	11.873	62.65	57.45	27.73	13.07
IR62A×ACI1R	9.17	2.63	25.93	3.373	1.113	30.04	11.20	18.50	5.33
IR68A x ACI1R	9.73	2.50	25.33	26.810	8.847	33.48	80.09	30.70	13.03
BRRI1A x ACI1R	8.57	2.87	20.53	38.287	12.635	64.95	58.94	35.63	15.07
Gan46A x ACI1R	8.83	3.00	30.67	43.433	14.333	70.10	61.96	31.90	13.43
IR58A×BHD1R	9.67	2.77	23.93	27.310	9.012	67.31	40.58	27.47	10.53
IR62A×BHD1R	9.13	2.67	19.87	19.507	6.437	59.51	32.95	26.27	10.77
IR68A x BHD1R	9.57	2.80	26.53	19.740	6.514	26.41	74.86	31.13	12.57
BRRI1A x BHD1R	8.70	2.83	26.77	30.623	10.106	43.96	69.67	28.83	12.30
Gan46A x BHD1R	8.43	2.17	24.47	40.723	13.439	54.06	75.32	26.53	13.53
IR58A×KataribhogR	10.37	2.30	19.73	24.933	8.228	44.93	55.51	26.37	11.40
IR62A×KataribhogR	8.60	2.37	15.13	9.293	3.067	15.96	58.25	39.37	12.77
IR68Ax KataribhogR	9.37	2.37	20.00	25.233	8.327	45.23	55.85	28.27	12.57
BRRI1AxKataribhogR	8.27	2.50	22.13	17.667	5.830	31.00	57.24	29.43	12.60
Gan46AxKataribhogR	8.77	2.73	22.73	12.723	4.199	39.39	32.30	12.74	4.23
IR58A	9.20	1.47	0.00	0.000	0.000	40.13	0.00	43.20	18.17
IR62A	9.17	2.03	0.00	0.000	0.000	38.35	0.00	48.27	16.05
IR 68888A	8.73	1.80	0.00	0.000	0.000	65.05	0.00	43.10	25.43
Gan46A	7.30	1.83	0.00	0.000	0.000	85.10	0.00	47.50	20.60
BRRI1A	8.27	1.60	0.00	0.000	0.000	54.81	0.00	39.40	52.80
Hera5R	10.10	2.03	23.92	15.700	5.180	32.21	47.29	38.90	12.28
BU7R	9.47	1.93	21.98	14.260	4.707	31.09	44.49	30.77	18.03
KataribhogR	8.78	1.75	16.70	30.980	10.223	64.07	58.76	31.33	12.83
BHD1R	9.00	2.13	34.50	24.050	7.937	52.03	52.50	21.43	10.40
ACI1R	9.87	2.00	26.75	21.260	7.017	43.20	51.77	34.83	14.87
Mean	9.17	2.59	20.23	19.731	6.511	44.11	47.14	30.47	13.97
LSD (0.05)	0.59	3.21	1.93	1.54	0.51	6.13	9.05	2.00	1.15
SED	0.30	1.64	0.98	0.79	0.26	3.13	4.62	1.02	0.59
Heritability in broad sense (H)	0.92	0.13	0.97	0.99	0.99	0.98	0.95	0.99	0.98
Level of significance	**	**	**	**	**	**	**	**	**

The parents showed variation in panicle length, which ranged from 23 cm to 27.03 cm (KataribhogR), with an average of 25 cm. In hybrids, the panicle length varied from 22.17 cm in IR62A x BU7R to 28.93 cm in IR62A x BHD1R.. The line Gan46A generated the most filled spikelet per panicle, while the line Hera5R produced the fewest filled spikelet per panicle. The range of filled spikelet per panicle in the cross combinations was 47-192, with Gan46A x BU7R revealing the most filled spikelet. The lines manifested considerable amount of variability for unfilled spikelet per panicle as the evident from the range which varied from 2(IR68A) to 21(BHD1R) with an average of 11.5 seed per panicle. A high magnitude of variability was also observed in the crosses reflected from a wide range which varied from 16 in IR68A x Hera5R to 78 in IR58A x BHD1R (Table 2).

The highest seed length was revealed by the parent IR58A (10.10 mm) followed by BHD1R (7.30 mm). In contrast, the cross of IR58A x BHD1R produced the longest seeds, measuring 10.53 mm, followed by BRRI1A x Hera5R, whose seeds were 8.20 mm. While BHD1R generated 2.13 mm of seed length, line IR58A produced 1.44 mm. In the cross of Gan46A x BHD1R, the seed breadth was 2.17 mm, while in the cross of IR62A x BU7R, it was 2.93 mm. The range of test weights for the lines ranged from 3.22 g (BRRI1A) to 35.40 g (BHD1R), with an average of 19.13 g, demonstrating a significant level of variability. A high magnitude of variability was observed in the crosses which reflected from a wide range which varied from 9.54g in IR62A x BU7R to 67.31g in IR58A x BHD1R.

Harvest index in the parents was from 32.91 % (IR62A) to 50.21 % (Kataribhogh R) with an average value of 46.87 %. The range of variation for parents was 4.70 g (BU7R) to 45.24 g (Gan46A) with an average of 23.55 g. In hybrids, the range of variation for biomass per plant was 17.77 g in hybrid Gan46A x BU7R, whereas in BRRI1A x Hera5R hybrids it was 0.16 g (Table 2).

The estimated grain Zn content among the parents was between 20.06 ppm (Hera5R) to 48.27 ppm (IR62A). The highest Zn content found in IR62A it was followed by 47.50 ppm (Gan46A), 45.20 ppm (IR58A), 38.80 ppm (Hera5R) and in hybrids, the range of variation for grain Zn content was 2.89 (IR62A x BU7R) to 42.73 (Gan46A x Hera5R) with an average value of 22.81 ppm. Highest in 42.73 (Gan46A x Hera5R) followed by 40.72 (Gan46A x BHD1R), 38.29 (Gan46A x BHD1R), 35.98 (IR58A x BHD1R), 30.62 (BRRI1A x BHD1R) hybrids (Fig. 1). The grain Fe content among the parents was between 10.20 ppm (BHD1R) to 52.80 ppm (BRRI1A) and in hybrids, the range of variation for grain Fe content was 1.11 (IR62A x BHD1R) to 14.10 (Gan46A x Hera5R) with an average value of 22.81 ppm (Fig. 2).

The highest seed yield was revealed by the parent Gan46A (45.12 g) followed by BU7R (14.18 g) among on the contrary, the cross combination BRRI1A x BHD1R performed highest grain yield per plant (g) as 80.09 whereas IR62A x BHD1R cross combination showed lowest grain yield per plant as 11.20 g. The grain yield (t/ha) among the parents was between 5.16 (t/ha) (Hera5R) and 14.89 (t/ha) (Gan46A) and in hybrids, the highest grain yield (t/ha) was 14.33 (BRRI1A x Hera5R) followed by 13.44 (BRRI1A x BHD1R) (Fig. 2).

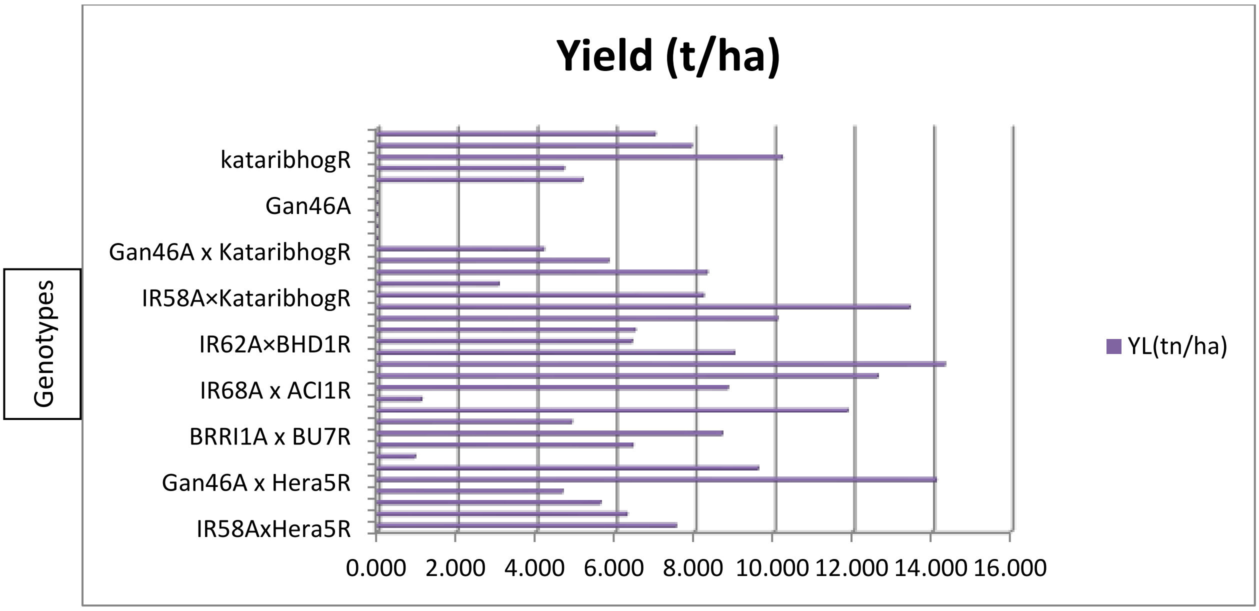

Figure 1: Mean performance of lines, testers and their hybrids for grain yield (t/ha)

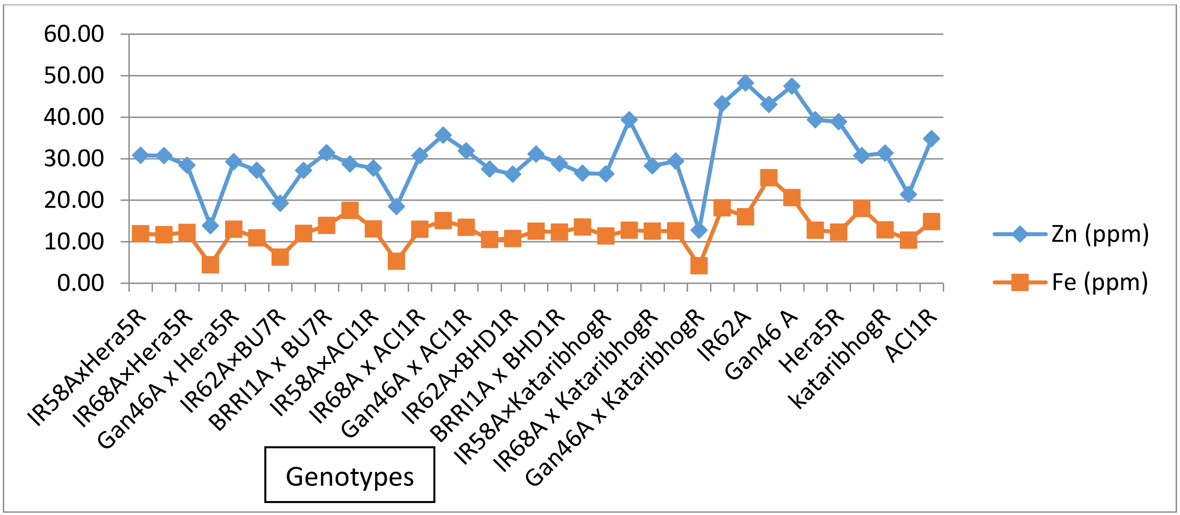

Figure 2: Mean performance of lines, testers and their hybrids for Zn and Fe content (ppm)

3.2 Genetic variability

A wide range of variation was found for all the traits among 25 rice genotypes which indicate that large genetic differences exist among the genotypes. Genotypic and phenotypic variance, Genotypic and Phenotypic coefficient of variation, broad sense heritability (%), genetic advance, genetic advance percent mean value for all the traits are given below in Table 3.

Table 3: Estimation of genetic parameter for twenty quantitative characteristics of rice hybrids

Parameter	σ^2g	σ^2p	GCV (%)	PCV (%)	Hb(%)	GA	GAPM
DFF	16.95	18.07	7.978	8.236	93.822	8.217	15.919
50% F	13.54	14.92	6.681	7.013	90.752	7.222	13.110
PF (%)	485.49	485.65	30.570	31.575	99.969	45.383	65.025
DM	2.468	2.757	1.868	1.975	89.506	3.062	3.641
PH	98.87	235.85	9.490	14.656	41.926	13.264	12.658
NPT	13.35	45.87	32.106	59.512	29.105	4.061	35.682
PL	4.15	6.58	7.915	9.957	63.186	3.338	12.960
NT	15.809	22.139	33.974	40.204	71.407	6.921	59.140
SY(g)	79.53	81.82	49.371	50.078	97.196	18.12	100.268
FS	1331.96	2428.94	27.239	36.784	54.837	55.674	41.553
UFS	1480.64	1905.43	71.718	81.358	77.706	69.875	130.234
GL(mm)	0.794	1.045	9.665	11.088	75.980	1.600	17.355
GB(mm)	0.525	1.97	26.040	50.393	26.702	0.771	27.720
BM (g/p)	255.67	258.83	40.139	40.386	98.780	32.737	82.180
HI(%)	352.85	360.1	35.954	36.322	97.985	38.304	73.316
ZC (ppm)	110.36	117.14	42.666	43.956	94.214	21.006	85.310
FC (ppm)	16.62	18.24	36.252	37.968	91.164	8.020	71.303
TSW (g)	140.24	141.1	54.380	54.546	99.391	24.321	111.680
GY (g/p)	213.04	216.68	33.662	34.514	95.122	16.931	67.631

Legend: DFF=Days to first flowering, 50%F=Days to Fifty Percent Flowering, DM=Days to Maturity, PF=Pollen Fertility, PH=Plant Height (cm), NPT=Number of Productive Tillers per hill, PL=Panicle Length(cm), NT=Number of tillers, SY= straw yield, TSW=Test Weight(g), GL=Grain Length (mm), GB=Grain Breadth(mm), BM=Biomass, HI=Harvest Index, ZC=Zinc Content (ppm), FC=Iron Content (ppm), GY=Grain Yield ton per hectare. σ2g=genotypic variance, σ2p=Phenotypic Variance, GCV= Genotypic Coefficient of Variation, PCV=Phenotypic Coefficient of Variation, Hb=Heritability, GA= Genetic Advance, GAPM=Genetic Advance % Mean Value

The genetic analysis showed that the Phenotypic Coefficient of Variation (PCV) was higher than Genotypic Coefficient of Variation (GCV) for all the characters studied indicating the presence of environmental influence to some degrees in the phenotypic expression of the characters. The difference between genotypic and phenotypic coefficients of variability indicates the environmental influence. The higher values of PCV and GCV further facilitate the possibility of improvement of those genotypes for the selection of desired characters. The values of PCV and GCV indicated that there were considerable variations for all the traits except days to first flowering and days to maturity. Among the traits, thousand grain weight exhibited high estimates of PCV (54.380 %) and GCV (54.546 %) followed by Zn content (42.666 % and 43.956 %) and straw yield (49.371 % and 50.078 %). Here, differences between GCV and PCV for thousand seed weight, Zn content were minimum, which indicated that very little environmental influence on the expression of these traits. The difference between GCV and PCV for number of productive tillers, number of tillers and grain breadth (mm) was higher which indicated that expression of these traits was vulnerable to environmental influence. Heritability estimated in broad sense was relatively high for all the traits studied. Although high heritability estimation has been found to be helpful in making selection of superior genotypes on the basis of phenotypic performance. Johnson (1955) [18] suggested that heritability estimates along with genetic gain were more useful in predicting the effect for selecting the best individual. The broad sense heritability demonstrated a high level of genetic control of variation for pollen fertility (%) and thousand seed weight. Broad sense heritability provides the basis for selection on phenotypic performance. We considered estimates of broad sense heritability and expected GAPM jointly for selection.

High heritability as well as high genetic advances as % of mean indicated that there was greater scope for efficient selection on pollen fertility and thousand seed weight, harvest index (%), biomass content and could be expected to improve these characters through selection. High heritability with low GAPM for days to maturity indicated that little inherent variability was available for direct selection on this trait and limits the selection practice. The results from the present study reported that pollen fertility (%) (99.96) and grain yield (t/ha) (99.365),) expressed high heritability (Table 3) coupled with high genetic advance.

High heritability values indicate that the traits under study are less influenced by environment for their phenotypic expression and selection could be made by using these traits to improve rice genotypes for grain yield (t/ha). In this study, high heritability with high genetic advance (GA) was found for the character of pollen fertility (%), biomass content, harvest index (%), Zn content, thousand seed weight with grain yield (t/ha) indicating the presence of additive gene effects in controlling those character.

3.3 Correlation analysis

In general, genotypic correlations were higher than phenotypic ones in magnitude for all the characters. The characters which showed negative correlation at genotypic level also showed negative correlation at phenotypic level. The results of the correlation analysis are presented in Table 4.

3.3.1 Phenotypic correlation coefficients

The Phenotypic correlation coefficients for all the characters were shown in Table 4. In hybrids, Days to first flowering showed highly significant positive correlation with 50% flowering (0.937**), days to maturity (0.445**), grain length (0.151**), Fe content (0.169**). Days to first flowering and days to maturity showed negative correlation with Harvest Index (%). Similar result was found by Nagesh *et al.,* (2012) [15] for days to days to first flowering and grain yield. Days to first flowering negatively correlated with others trait. In hybrids, Days to 50% flowering showed highly significant positive correlation with days to maturity followed by productive tillers (0.214**) and filled grain (0.186**). Days to 50% flowering significantly negative correlation with number of tillers per plant (-.0323**) followed by biomass (-0.18**), harvest index (%) (-0.247**), Zn content (-0.214**), Fe (-0.202**) and thousand seed weight (-0.278**), grain yield (t/ha) (-0.280**). In hybrids, highly significant and positive correlation was observed for pollen fertility with grain yield (t/ha) (0.378**). Pollen fertility also positively significant with filled grain (0.277**), panicle length (0.167**), biomass (0.311**), harvest index % (0.328**), Zn (0.264**) and Fe content (0.28**), thousand seed weight (0.378**), grain yield per plant (0.186**). In hybrids, a significant positive correlation was observed for days to maturity with unfilled grain (0.184**) and grain length (0.38*). Days to maturity is non-significant with others traits in this study. In hybrids, plants height exhibited (Table 4) a significant positive correlation with productive tillers (0.204**), panicle length (0.425**), number of tillers (0.287**), straw yield (0.293**), unfilled seed (0.270**), biomass (0.172*), thousand seed weight grain yield per plant. Grain length (-0.290), harvest index (-0.181**) and grain yield per plant (-0.186**) had significant negative correlation with plant height. In hybrids, a significant positive correlation was observed for total number of Productive tillers per plant with panicle length (0.175**), number of tillers (0.559**), straw yield (0.156**) and biomass (0.160**). In hybrids, Panicle length showed significant negative correlation with grain length (-0.130*) and grain yield per plant (-0.136*), grain length (mm) (-0.139*). In hybrids, highly significant and positive correlation was observed for grain yield per plant with filled seed (0.331*), unfilled seed (0.202*), grain length (0.242**), harvest index (0.256*), Zn content (0.244**), Fe content (0.224**), and thousand seed weight (0.191**). This result was in conformity with the reports by Ravindra (1996) [22] and Nagesh *et al.,* (2012) [5]. Number of tillers per plant showed a significant and positive correlation with number of productive tillers. Zn content showed significant positive filled grain (0.260**), grain length (0.313**), biomass (0.051**), harvest index % (0.721**), Fe content (0.817**) and thousand seed weight (0.693**), grain yield (g/p) (0.244**), grain yield (t/ha) (0.700**) Fe content showed positively correlated with pollen fertility (0.630**), filled grain, grain length, biomass, harvest index, thousand seed weight and grain yield per plant (0.224**) in hybrids. The highest correlations existing between different plant traits can be used to conduct indirect selection of a desired trait in a breeding program. This result was in conformity with the results of Shi *et al.,* (2008) [23] and Nagesh *et al.,* (2012) [5].

3.3.2 Genotypic correlation coefficient

Days to first flowering showed highly significant positive correlation with 50% flowering (0.946**), days to maturity (0.447**), filled grain (0.255**), grain length (0.168**). Days to first flowering and days to maturity showed negative correlation with Harvest Index (-0.196**) and other traits (Table 4). Days to 50% flowering significantly negative correlation with number of productive tillers (-0.389**), number of tillers per plant (-0.407**), Plant height (-0.128**) and filled grain (-0.275**), biomass (-0195**), harvest index % (-0.264**), Zn content (-0.214**) and Fe content (-0.202**). Highly significant and positive correlation was observed for pollen fertility (%) with grain yield (t/ha) (0.378**). Pollen fertility also positively significant with filled grain (0.376**), panicle length (0.211**), biomass (0.312**), harvest index (0.332**), Zn (0.272**) and Fe content (0.293**), thousand seed weight (0.379**), grain yield per plant (0.191*). Plants height exhibited a significant positive correlation with productive tillers (0.517**), panicle length (0756**), number of tillers (0.486**), straw yield (0.468**), unfilled seed (0.050**), biomass (0.273**), thousand seed weight, grain yield per plant. Filled grain, Grain length, harvest index and grain yield per plant had significant negative correlation with plant height (Table 4). A significant positive correlation was observed for filled grain, biomass. Panicle length showed significant negative correlation with grain length. Highly significant and positive correlation was observed for grain yield per plant with pollen fertility, filled seed, grain length, harvest index, Zn content, Fe content and thousand seed weight. Breeding for high grain Zn concentration and enhancement of grain yield per plant has to be designed randomly. Fe content showed positively correlated with pollen fertility, filled grain, grain length, biomass, harvest index, thousand seed weight and grain yield per plant (Table 4).

Table 4: Estimation of phenotypic (r_p) correlation coefficient and genotypic (r_g) correlation coefficient among 20 characters of rice hybrids

Para meter		DFF	50% F	PF (%)	DM	PH (cm)	PT	PL (cm)	NPT	SY (g)	FS	UFS	GL (mm)	GB (mm)	BM (g/p)	HI (%)	Zn (ppm)	Fe (ppm)	TSW (g)	GY (g/p)
DFF	r_p	0.937**																		
	r_g	0.946**																		
50%F	r_p	-0.002NS	0.016NS																	
	r_g	-0.002 NS	0.017NS																	
PF%	r_p	0.445**	0.410**	0.069NS																
	r_g	0.447**	0.412**	0.072NS																
DM	r_p	-0.157**	0.095NS	-0.011NS	0.005NS															
	r_g	-0.230**	-0.128*	-0.018NS	0.641NS															
PH	r_p	-0.220**	0.214**	-0.028NS	-0.009NS	0.204**														
	r_g	-0.395**	-0.389**	-0.057NS	-0.032NS	0.517**														
PT	r_p	-0.089NS	-0.001NS	0.167**	0.095NS	0.425**	0.175**													
	r_g	-0.101NS	0.014NS	0.211**	0.149**	0.756**	0.380**													
PL	r_p	-0.329**	-0.323**	-0.671**	-0.071NS	0.287**	0.559**	0.182**												
	r_g	-0.404**	-0.407**	-0.200**	-0.103NS	0.486**	0.909**	0.237**												
NTP	r_p	-0.031NS	0.045NS	0.055NS	0.093NS	0.293**	0.156**	0.225**	0.271**											
	r_g	-0.035NS	0.046NS	0.055NS	0.095NS	0.468**	0.294**	0.286**	0.328**											
SY (g)	r_p	-0.180**	0.186**	0.277**	-0.030NS	-0.059NS	-0.125*	0.195**	-0.245**	-0.143*										
	r_g	0.256**	-0.275**	0.376**	-0.059NS	-0.171**	0.179**	0.286**	-0.364**	-0.189**										
FS	r_p	0.046NS	0.075NS	-0.271**	0.121*	0.270**	0.104NS	0.143*	0.379**	0.256**	-0.323**									
	r_g	0.052NS	0.091NS	-0.309**	0.184**	0.500**	-0.215**	0.191**	0.430**	0.290**	-0.455*									
UFS	r_p	0.151**	0.052NS	0.024NS	0.382*	-0.290**	-0.139*	-0.130*	-0.274**	-0.193**	0.278**	-0.213**								
	r_g	0.168**	0.060NS	0.028NS	0.146*	-0.528**	-0.311**	-0.140*	-0.392**	-0.224**	0.403*	0.298**								
GL (mm)	r_p	-0.017NS	0.010NS	0.063NS	0.006NS	-0.023NS	-0.038NS	-0.020NS	-0.108NS	0.047NS	-0.001NS	-0.076NS	0.021NS							
	r_g	-0.110NS	-0.060NS	0.123*	-0.146*	-0.056NS	-0144*	0.161**	-0.168**	0.084NS	0.149*	-0.221**	0.053NS							
GB (mm)	r_p	-0.213**	-0.180**	0.311**	0.035NS	0.172**	0.160**	0.221**	0.121*	-0.683**	0.171**	-0.180*	0.023NS	0.042NS						
	r_g	-0.225**	-0.195**	0.312**	0.034NS	0.273**	0.290**	0.280**	0.144*	0.681**	0.226*	-0.138*	0.026NS	0.059NS						
BM (g/p)	r_p	-0.188**	-0.247**	0.328**	-0.372NS	-0.181**	-0.039NS	-0.010NS	-0.226**	-0.434**	0.380**	-0.501**	0.321**	-0.032NS	0.310**					
	r_g	-0.196**	-0.264**	0.332**	-0.037NS	-0.285**	-0.082NS	-0.013NS	-0.274**	-0.426**	0.495*	-0.574**	0.370**	-0.073NS	0.323**					
HI (%)	r_p	-0.176**	-0.214**	0.264**	-0.022NS	-0.053NS	0.044NS	0.052NS	0.105NS	-0.021NS	0.260**	-0.355**	0.313**	-0.015NS	0.051**	0.721**				
	r_g	-0.183**	-0.226**	0.272**	0.025NS	-0.089NS	0.083NS	0.059NS	-0.127*	-0.018NS	0.342*	-0.409**	0.349**	-0.017NS	0.526**	0.747**				
Zn (ppm)	r_p	0.169**	-0.202**	0.281**	0.010NS	-0.028NS	0.004NS	0.082NS	-0.183**	-0.007NS	0.353**	-0.394**	0.231**	0.009NS	0.474**	0.663**	0.817**			
	r_g	-0.183**	-0.232**	0.293**	0.001NS	0.051NS	-0.017NS	0.114*	-0.216**	-0.010NS	0.502*	-0.458**	0.251**	0.004NS	0.502**	0.706**	0.854**			
Fe (ppm)	r_p	-0.630**	-0.278**	0.378**	-0.023NS	0.008NS	0.097NS	0.127*	-0.044NS	0.162**	0.339**	-0.356**	0.573**	0.020NS	0.831**	0.749**	0.698**	0.650**		
	r_g	-0.274**	-0.296**	0.379**	-0.024NS	0.014NS	0.169**	0.159**	-0.055NS	0.165**	0.444*	-0.406**	0.200**	0.015NS	0.834**	0.754**	0.721**	0.684**		
TSW (g)	r_p	-0.015NS	-0.160NS	0.186**	-0.035NS	-0.186**	-0.064NS	-0.136*	-0.209**	-0.118*	0.331*	0.202*	0.242**	0.051NS	0.070NS	0.256**	0.244**	0.224**	0.191**	
	r_g	-0.013NS	-0.012NS	0.191**	-0.033NS	-0.247**	-0.132*	-0177**	-0.262**	-0.121*	0.187*	-0.823**	0.279**	0.105NS	0.080NS	0.268**	0.254**	0.238**	0.190**	
GY (g/p)	r_p	-0.266**	-0.280**	0.378**	-0.023NS	0.010NS	0.098NS	0.129*	-0.043NS	0.164**	0.340**	-0.355**	0.575**	0.021NS	0.832**	0.749**	0.700**	0.649**	0.910**	0.192**
	r_g	-0.276**	-0.298**	0.380**	-0.241NS	0.017NS	0.171**	0.162**	-0.053NS	0.166**	0.448*	-0404**	0.204**	0.017NS	0.835**	0.754**	0.722**	0.684**	0.930**	0.200**

*and** indicate significance at 5% and 1% levels respectively

Legend: DFF=Days to first flowering, 50%H=Days to Fifty Percent Flowering, DM=Days to Maturity, PF=Pollen Fertility, PH=Plant Height(cm), NPT=Number of Productive Tillers per hill, PL=Panicle Length(cm), NT=Number of tillers, SY= straw yield, TSW=Test Weight(g), GL=Grain Length(mm), GB=Grain Breadth(mm), BM= Biomass, HI= Harvest Index, ZC=Zinc Content(ppm), FC=Iron Content(ppm), GY= Grain Yield ton per hectare.

3.4 Genotypic Path Coefficient

Both the genotypic and phenotypic coefficient of all the traits on yield was portioned into direct and indirect effects through path coefficient analysis. Path-coefficient computed on the basis of genotypic correlation is given in Table 5. The highest positive direct contribution on grain yield/plant at genotypic level was expressed by thousand seed weight (2.214) followed by straw yield/plant (G) (0.947), plant height (0.078), days to 50% flowering (0.057), no. of tillers (0.051), harvest index (0.045), filled grain (0.043), grain length (0.029), grain breadth (0.018), Zn content (0.005) and pollen fertility% (0.003). In contrast negative direct effect on Grain yield/plant was exerted by biomass content (-1.00), panicle length (-.067). The direct effect of rest of the characters on Grain yield/plant was negligible. The highest positive indirect effects on Grain yield per plant of thousand seed weight (1.670) followed by straw yield, Number of tillers and 50 % flowering, plant height. The remaining estimates of indirect effects in this analysis were too low to be considered of any consequence. The estimates of residual factors were negligible. These results are similar to Zahid *et al.,* (2006) [24], Kiami *et al.,* (2012) [25], Kiami and Nemadzadeh (2012) [26], Krishnamurthy and Kumar (2012) [27], Seyom *et al.,* (2012) [28], Sudharani *et al.,* (2013) [29], Bhatia *et al.,* (2013) [30], Lakshmi *et al.,* (2014) [31], Gopikannan and Ganesh (2014) [32] and Kolom *et al.,* (2015) [33]. If the association with the causal factor the effect was almost equal to its direct effects, the correlation explains the true relationship and the direct selection through its traits might be effective. When the value of direct effect and the correlation coefficient vary, indirect effects play an important role. In such a situation the indirect causal factors are also to be considered simultaneously during selection.

Table 5: Path coefficient analysis showing direct and indirect effects of different traits of rice at genotypic level

Parameters	DFF	50% F	PF (%)	DM	PH	NPT	PL cm	NT	SY(g)	FS	UFS	GL (mm)	GB (mm)	BM (g/p)	HI (%)	ZC (ppm)	FC (ppm)	TSW (g)	GY (g/p)	GY (tn/ha)
DFF	**-0.027**	0.054	-.001	-0.007	-0.017	0.008	0.006	-0.020	-0.033	-0.011	-0.003	0.004	-0.002	0.377	-0.008	-0.001	0.003	-0.607	0.002	-0.276**
50% F	-0.025	**0.057**	0.005	-0.007	-0.009	0.008	-0.009	-0.080	0.004	-0.011	-0.005	0.002	-0.001	0.327	-0.012	-0.001	0.003	-0.655	0.002	0.298**
PF (%)	0.005	0.009	**0.003**	-0.001	-0.001	-0.001	-0.014	-0.010	-0.052	0.016	0.001	0.008	0.002	-0.524	0.015	0.001	-0.004	0.839	-0.003	0.380**
DM	-0.01	0.023	0.002	**-0.002**	0.004	0.007	-0.009	-0.005	-0.088	-0.002	-0.001	0.004	-0.002	-0.057	-0.001	0.001	-0.001	-0.052	0.005	-0.024^{NS}
PH	0.006	-0.007	-0.006	-0.001	**0.078**	-0.041	-0.049	0.443	0.443	-0.007	-0.002	-0.015	-0.001	-0.457	-0.013	-0.024	0.008	0.030	0.004	0.01^{NS}
NPT	0.010	-0.022	0.001	0.006	0.040	**-0.022**	-0.025	0.046	0.279	-0.007	-0.001	-0.009	-0.002	-0.488	-0.003	0.004	0.002	0.375	0.002	0.171**
PL	0.002	0.008	0.006	-0.002	0.059	-0.008	**-0.067**	0.012	0.271	0.012	-0.001	-0.004	0.002	-0.469	-0.005	0.003	-0.001	0.351	0.002	0.162**
NT	0.011	0.023	-0.006	0.001	0.037	-0.019	0.015	**0.051**	0.311	-0.015	-0.002	-0.011	-0.003	0.241	-0.012	-0.007	0.003	-0.011	0.004	-0.053^{NS}
SY(g)	0.009	0.002	0.001	-0.001	0.036	-0.006	-0.018	0.016	**0.947**	-0.008	-0.001	-0.006	0.001	-1.143	-0.019	-0.001	0.001	0.364	0.002	0.166**
FS	0.007	-0.015	0.001	0.001	-0.013	0.003	-0.018	-0.018	-0.179	**0.043**	0.002	0.011	0.002	-0.379	0.022	0.001	-0.008	0.982	-0.003	0.446*
UFS	-0.001	0.005	-0.009	-0.003	0.038	-0.004	-0.012	0.022	0.274	-0.019	**-0.005**	-0.008	-0.004	0.231	-0.026	-0.002	0.007	-0.898	0.003	-0.404**
GL(mm)	-0.004	0.003	0.009	-0.002	0.041	0.006	0.009	-0.020	-0.212	0.017	0.001	**0.029**	0.009	-0.043	0.016	0.001	-0.004	0.442	-0.004	0.204**
GB(mm)	0.003	-0.003	0.003	0.002	-0.004	0.003	-0.010	-0.008	0.079	0.006	0.001	0.001	**0.018**	-0.098	-0.003	-0.008	-0.006	0.032	-0.001	0.017^{NS}
BM (g/p)	0.006	-0.011	0.009	-0.006	0.021	-0.006	-0.018	0.007	0.645	0.009	0.008	0.007	0.001	**-1.00**	0.014	0.002	-0.008	1.00	-0.001	0.835**
HI(%)	0.005	-0.015	0.001	0.006	-0.022	0.001	0.008	-0.214	-0.403	0.021	0.003	0.010	-0.001	-0.541	**0.045**	0.004	-0.011	1.670	-0.004	0.755**
ZC (ppm)	0.005	-013	0.048	-0.004	-0.006	-0.001	-0.003	-0.06	-0.016	0.014	0.002	0.010	-0.002	-0.883	0.034	**0.005**	-0.014	1.596	0.004	0.722**
FC (ppm)	0.005	-0.013	0.009	-0.000	-0.003	0.003	-0.007	-0.011	-0.009	0.021	0.002	0.007	0.007	-0.842	0.032	0.004	**-0.016**	1.514	-0.003	0.684**
TSW (g)	0.007	-0.017	0.001	0.004	0.001	-0.003	-0.010	-0.002	0.155	0.019	0.002	0.005	0.002	-1.400	0.034	0.003	-0.011	**2.214**	-0.003	1.000**
GY (g/p)	0.003	-0.006	0.005	0.006	-0.019	0.002	0.011	-0.013	-0.114	0.008	0.001	0.008	0.001	-0.135	0.012	0.001	-0.004	0.440	**-0.001**	0.200**

Residual Effect (R) = -0.00006, *and** indicate significance at 5% and 1% levels respectively

Legend: DFF=Days to first flowering, 50%F=Days to Fifty Percent Flowering, DM=Days to Maturity, PF=Pollen Fertility, PH=Plant Height(cm), NPT=Number of Productive Tillers per hill, PL=Panicle Length(cm), NT=Number of tillers, SY= straw yield, TSW=Test Weight(g), GL=Grain Length(mm), GB=Grain Breadth(mm), BM= Biomass, HI= Harvest Index, ZC=Zinc Content(ppm), FC=Iron Content(ppm), GY= Grain Yield ton per hectare.

IV. CONCLUSION

Among the genotypes, IR62A and Gan46A x KataribhoghR had better mean performance for Zn content in parent and hybrids, respectively. Among the traits, thousand grain weight followed by Zn content and straw yield exhibited PCV and GCV close to each other's indicate less importance of environment for expressing of these traits. Pollen fertility (%) (99.96) coupled with grain yield (t/ha) (99.365),) expressed high heritability. In hybrids, highly significant and positive phenotypic correlation was observed for grain yield per plant with filled seed, unfilled seed, grain length, harvest index, Zn content, Fe content, and thousand seed weight. Highly significant positive correlation was present between Zn content with grain yield per plant. This suggested that these traits seem to be similarly controlled. Hence, breeding for high grain Zn concentration and enhancement of grain yield per plant has to be designed in specific way. Significant positive correlation was also observed for grain Zn content with the pollen fertility, number of filled grain per panicle, grain length, biomass of the plant, and also with the harvest index (%) per panicle. The highest positive direct contribution on grain yield/plant at genotypic level was expressed by thousand seed weight followed by straw yield/plant (g), plant height, days to 50% flowering, no. of tillers, harvest index, filled grain, grain length, grain breadth, Zn content and pollen fertility%.

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