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Principal component analysis of yield and quality traits in Zinc rich landraces of rice (*Oryza sativa* L.)

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Abstract

Principal Component Analysis (PCA) was carried out to find the genetic divergence among 35 zinc-rich landraces of rice along with two checks for yield and quality traits. Three principal components with Eigen value more than one explained maximum variation with a total contribution of 78.33 per cent of the total variability. Principal Component 1 (PC 1) contributed a maximum of 51.71 per cent, while PC 2 contributed to 18.71 per cent and PC 3 contributed to 7.96 per cent towards the total variability. Yield and quality traits *such as* days to 50 per cent flowering, number of productive tillers plant⁻¹, grain yield plant⁻¹, head rice recovery per cent, iron content and volume expansion ratio explained the maximum variance in PC 1. The results of the 2D scatter diagram revealed GM-120 and GM-173 landraces to be the most diverse. These genotypes were identified to be high yielding and nutritionally rich, compared to BPT 5204. Hybridization of these genotypes is expected to result in desirable transgressive segregants for yield, quality and nutritional traits.

Keywords: Principal component analysis, Yield components, Quality traits, Zn, Fe.

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple cereal food crop of more than half of the world's population and hence, it is considered as a Global grain. Among the rice-producing countries, India is the largest producer next to China. In India, it is grown in an area of 43.78 million hectares with an annual production of 118.43 million tones and productivity of about 2705 kg/ha (Agricultural Statistics at a Glance- 2021). Rice crop accounts for about 30% of the calories needed for the country's population (Maclean, 2002).

Among the essential micronutrients, zinc (Zn) and iron (Fe) are vital for maintaining the growth and development of human beings and plants. Recent studies have

indicated that 17.3% of the world's population is zinc-deficient (Hefferon 2019). Malnutrition in humans also referred to as hidden hunger, is caused by a deficiency of essential nutrients like zinc and iron. It leads to several health disorders such as dwarfism, anorexia, weak immunity, growth retardation, loss of appetite, hair loss, diarrhoea, weight loss, and delayed healing of wounds (Wang and Busbey 2005). Therefore, improving the bio-availability of nutrients such as zinc and iron in rice grain *via* genetic selection through plant breeding can provide a sustainable solution to hidden hunger. Knowledge on the nature and degree of genetic diversity of high zinc and iron landraces is essential for planning an efficient bio-fortification program.

Principal Component Analysis (PCA) has been used frequently for genetic diversity studies in several crops such as rice (Bharadwaj *et al.*, 2001 and Francis and Packiaraj, 2020) and wheat (Hailu *et al.*, 2006), etc. The main advantage of PCA over cluster analysis is that each genotype can be assigned to one group only (Mohammadi, 2002). Further, PCA allows the natural grouping of the genotypes and is an accurate indicator of differences among genotypes and PCA scores are important in drawing conclusions for selecting promising genotypes. The present study was undertaken in this context to identify the nature and magnitude of genetic diversity among 35 zinc-rich landraces along with two checks for their yield and quality traits using Principal Component Analysis.

MATERIALS AND METHODS

The experimental material consisted of 35 zinc-rich rice landraces from all over India. The seed of these accessions was collected from the Indian Institute of Rice Research (IIRR), Hyderabad. Two local checks obtained from Regional Agricultural Research Station (RARS), Maruteru viz., MTU 7029 and BPT 5204 were grown together with the 35 zinc rich landraces (**Table 1**) during *Kharif* 2021 in a Randomized Block Design (RBD) with two replications. Seedlings were transplanted 28 days after sowing with a spacing of 20×15 cm. All the recommended practices were adopted to ensure a good crop stand. Morphological observations were recorded on yield, yield attributing and quality traits in five randomly selected plants for grain yield plant⁻¹ (g), plant height (cm), the number of productive tillers plant⁻¹, panicle length (cm), the number of grains panicle⁻¹ and test weight (g). Days to 50 per cent flowering were recorded on a plot basis.

Energy-dispersive X-ray Fluorescence Spectrometry (ED-XRF) was used for analyzing the grain zinc and iron content in brown rice at IIRR Hyderabad. All remaining grain quality parameters, *namely*, hulling recovery (%), milling recovery (%), head rice recovery (%), water uptake (ml) and volume expansion ratio were estimated at RARS, Maruteru, Andhra Pradesh. Principal component analysis was carried out using the software Window Stat Version 8.5.

RESULTS AND DISCUSSION

The Analysis of Variance (ANOVA) for yield and quality traits showed highly significant differences among the genotypes for all the characters under study, indicating the existence of adequate variation in experimental material. The mean performance of the zinc rich landraces with respect to yield, yield attributes and quality traits is presented in **Table 2**. Days to 50 per cent flowering varied from 66 (GM-163) to 119 days (MTU 7029), with an overall mean value is 76 days. The plant height ranged from 93cm (MTU 7029) to 170 cm (GM 22), with an overall mean value of 139 cm. The number of productive tillers plant⁻¹ varied from 11 (GM-122) to 16 (GM-169), with an overall

mean value of (13). The panicle length ranged from GM-18 (21.59 cm) to GM-94 (32.71 cm), with an overall average of 26.42 cm. One of the important yield influencing traits is the number of filled grains panicle⁻¹. It was noticed to be minimum in GM-127 (185) and maximum in GM-163 (319) with an overall average of 246. Maximum test weight was recorded in GM-178 (24.79g) while minimum in BPT-5204 (13.89 g), with an overall mean of 21.57g. Grain yield plant⁻¹ was observed to range from 14.59g (GM-129) to 29.09g (GM-120) with an overall mean value of 20.44g, indicating high variability among the genotypes for grain yield. A perusal of the results also revealed significantly higher grain yield plant⁻¹ in a few zinc rich landraces viz., GM-120, GM-173, GM-88 and GM-18 compared to the best high yielding check, MTU 7029 (23.58g).

Among the micronutrients, zinc (Zn) and iron (Fe) are vital nutrients that improve human health and curtail the risk of malnutrition. In the present investigation, the highest zinc content was observed for GM-163 (35.77 ppm), while the lowest zinc content was recorded in MTU-7029 (19.25 ppm) with an overall mean value of 27.07 ppm. Further, iron content varied from MTU-7029 (6.95 ppm) to GM-163 (15.92 ppm) with an average value of 11.46 ppm. A perusal of the results revealed significantly greater zinc and iron content compared to the check, BPT 5204 (Zn=20.36 ppm; Fe=7.99 ppm) in all the landraces studied. The highest Hulling recovery percentage was noticed in GM-173(64.91) while lowest in GM-91 (82.13) with an overall mean value of 75.04. The maximum milling recovery percentage was recorded for GM-91 (74.84) and minimum in GM-120 (57.98) with an overall average of 67.40. Head rice recovery ranged from 53.88 per cent (GM-173) to 63.53 per cent (MTU-7029) with a mean of 59.20 per cent. The lowest water uptake value was recorded in GM-125 (115.25) and the highest in MTU-7029 (181.25) with an overall mean value of 145.96. The maximum volume expansion ratio was recorded in GM-117(3.04) and minimum in BPT-5204 (4.65) with an overall mean value is 3.56. Based on the above *per se* performance four landraces were identified as potential zinc rich landraces with significantly high yield, compared to the checks and are presented in **Table 3** and **Fig.1**.

PCA revealed 78.33 per cent contribution of the first three principal components to the total variability (**Table 4**) indicating that the fundamental features of the data set are represented in the first three principal components. The principal components with the Eigen values less than one were considered non-significant. The first principal component (PC 1) contributed 51.71 per cent to the total variability. The characters days to 50 (%) flowering (0.364), the number of productive tillers/plant (0.356), head rice recovery (%) (0.297), volume expansion ratio (0.290), water uptake (ml) (0.271), and iron content (0.282) represented the maximum variance in this component. Hence, the selection of lines and traits from this PC will be useful. The second principal

Table 1. Details of the experimental material studied

S.No	Code	Entry Name	Source/ Origin
1	GM-7	Lalmala	Jammu Kashmir, India
2	GM-12	Raj Bangalo-1	West Bengal, India
3	GM-16	Futuyu-Red	China
4	GM-17	Futuyu	China
5	GM-18	Lalkada-1	Gujarat, India
6	GM-22	Pokkali-1	Kerala, India
7	GM-32	Ranbir basmati	Jammu Kashmir, India
8	GM-42	Nagaland selection-12	Nagaland, India
9	GM-44	Selection form Madhya Pradesh	Madhya Pradesh, India
10	GM-79	Selection form Madhya Pradesh	Madhya Pradesh, India
11	GM-80	Selection form Gujarat	Gujarat, India
12	GM-86	Selection form Maharashtra	Maharashtra, India
13	GM-87	Selection form Madhya Pradesh	Madhya Pradesh, India
14	GM-88	Selection form Punjab	Punjab, India
15	GM-91	Selection form Maharashtra	Maharashtra, India
16	GM-93	Selection form Gujarat	Gujarat, India
17	GM-94	Selection form Gujarat	Gujarat, India
18	GM-117	Selection form Maharashtra	Maharashtra, India
19	GM-120	Selection form Gujarat	Gujarat, India
20	GM-122	Selection form Kerala	Kerala, India
21	GM-124	Selection form Gujarat	Gujarat, India
22	GM-125	Selection form Madhya Pradesh	Madhya Pradesh, India
23	GM-127	Selection form Madhya Pradesh	Madhya Pradesh, India
24	GM-128	Selection form Madhya Pradesh	Madhya Pradesh, India
25	GM-129	Selection form Madhya Pradesh	Madhya Pradesh, India
26	GM-155	Chakho selection	Manipur, India
27	GM-156	Panval-1	Maharashtra, India
28	GM-157	Leelabati	West Bengal, India
29	GM-163	Shalimar	Jammu Kashmir, India
30	GM-167	Kamad	Chhattisgarh, India
31	GM-169	Dehradun basmati 3-6	Uttarakhand, India
32	GM-172	Dehradun basmati 2-2	Uttarakhand, India
33	GM-173	Dehradun basmati 1-10	Uttarakhand, India
34	GM-175	Dehradun basmati 1-8	Uttarakhand, India
35	GM-178	Dehradun basmati 1-5	Uttarakhand, India
36		MTU-7029 ©	Andhra Pradesh, India
37		BPT-5204 ©	Andhra Pradesh, India

component (PC 2) contributed to 18.716 per cent of the total variance. The characteristics such as grain yield/plant and grains panicle⁻¹ (0.204) described the highest loadings in this component. The third principal component (PC 3) was illustrated by 7.90 per cent contribution toward the total variability. The characters, test weight (0.330), water uptake (ml) (0.134), and grain yield plant⁻¹ (0.034) recorded maximum variance in this component.

The maximum contributing traits towards the genetic diversity of the zinc rich landraces are identified as, days to 50% flowering, productive tillers plant⁻¹, grain yield plant⁻¹, the number of grains panicle⁻¹, test weight, iron content, head rice recovery, water uptake, hulling recovery (%) and volume expansion ratio. Similar results were noted earlier by Tiwari *et al.* (2022) for days to 50% flowering and grain yield plant⁻¹; Sudeepthi *et al.* (2020)

Table 2. Mean performances for yield, yield components and quality traits in zinc-rich landraces of rice

S.No	Genotypes	Days to 50% flowering	Plant height (cm)	Number of productive tillers plant ⁻¹	Panicle length (cm)	Grains panicle ⁻¹	Grain yield plant ⁻¹ (g)	Thousand seed weight (g)	Zinc content (ppm)	Iron content (ppm)	Hulling recovery percent	Milling recovery percent	Head rice recovery	Water Uptake (ml)	Volume expansion ratio
1	GM-7	69	152.00	15	24.00	205	16.84	19.93	31.62	10.32	70.88	64.41	59.06	132.38	3.78
2	GM-12	76	129.50	12	26.60	219	21.08	18.19	25.30	11.03	71.74	64.76	60.06	129.00	3.85
3	GM-16	67	134.50	15	26.62	231	24.21	22.54	27.18	10.29	74.99	65.67	56.99	115.25	3.84
4	GM-17	75	133.00	13	24.72	262	21.12	22.48	31.69	11.28	74.82	69.19	59.45	160.25	3.71
5	GM-18	75	128.50	15	21.59	227	26.80	21.51	30.59	11.25	74.57	64.06	59.81	135.50	3.38
6	GM-22	70	170.00	13	24.11	242	24.62	24.12	31.37	11.07	80.41	73.75	60.19	141.50	3.35
7	GM-32	81	156.50	13	27.81	201	18.15	20.24	25.76	11.32	71.51	65.19	58.54	165.25	3.56
8	GM-42	68	149.00	13	25.43	222	24.79	23.35	25.22	11.86	71.78	65.90	57.99	166.75	3.21
9	GM-44	67	127.00	12	24.33	209	18.98	20.67	24.12	10.99	71.69	63.54	55.55	136.25	3.15
10	GM-79	76	149.50	15	30.12	197	21.24	21.67	31.54	10.71	80.50	71.84	57.95	163.50	3.63
11	GM-80	77	151.50	15	29.95	214	18.63	21.31	27.62	12.59	76.51	72.68	63.31	161.00	3.10
12	GM-86	92	153.00	14	23.66	238	20.98	24.26	31.72	11.89	76.34	65.76	57.98	121.00	4.08
13	GM-87	76	118.00	13	26.22	253	18.60	19.96	25.54	11.84	81.50	72.54	63.85	136.50	3.44
14	GM-88	89	149.50	13	23.33	264	26.24	22.16	30.73	11.96	71.35	65.08	57.63	143.00	3.04
15	GM-91	74	144.00	14	23.70	256	17.13	18.71	27.21	12.76	82.13	74.84	59.78	170.25	3.11
16	GM-93	67	133.50	13	23.66	243	24.14	23.13	25.86	13.54	81.06	72.48	58.69	122.50	3.34
17	GM-94	75	130.00	14	32.71	219	17.01	21.13	26.52	12.16	74.70	65.40	60.11	162.00	3.77
18	GM-117	78	130.50	13	23.37	192	16.95	20.67	26.49	13.18	75.46	67.55	54.63	174.61	3.04
19	GM-120	74	156.50	15	23.61	271	29.09	24.62	27.69	11.01	65.34	57.98	55.59	115.25	3.43
20	GM-122	76	151.00	11	26.54	310	22.88	21.49	28.01	11.36	70.19	64.81	59.10	118.50	3.14
21	GM-124	68	139.00	12	25.55	304	20.23	19.27	27.93	10.06	74.72	69.62	58.03	172.16	3.64
22	GM-125	70	132.50	13	30.07	210	18.24	22.90	27.83	10.57	69.58	62.01	55.10	158.90	3.51
23	GM-127	76	146.50	13	30.31	189	16.23	21.07	26.20	10.35	74.95	65.38	59.08	118.00	3.55
24	GM-128	74	139.00	14	26.06	253	17.69	23.25	25.80	10.70	74.42	65.52	58.16	134.01	3.35
25	GM-129	69	130.00	15	26.44	304	14.59	19.46	27.29	11.04	80.79	71.24	60.29	125.50	3.77
26	GM-155	76	128.50	14	25.32	244	19.07	20.07	26.13	11.76	81.97	72.24	58.88	125.18	3.77
27	GM-156	75	150.50	13	27.36	271	16.86	21.55	24.61	12.03	74.83	66.40	56.17	155.60	3.21
28	GM-157	67	144.50	14	26.80	263	18.78	19.71	25.90	12.01	75.11	68.23	60.77	124.50	3.34
29	GM-163	66	120.00	15	23.97	321	16.76	24.17	35.77	15.92	74.22	68.28	63.56	142.25	3.95
30	GM-167	78	150.50	15	27.20	312	17.26	22.99	26.23	13.51	81.04	72.91	62.78	146.50	3.72
31	GM-169	75	161.50	16	25.62	254	18.88	24.39	25.61	11.11	72.07	64.58	59.25	144.25	3.29
32	GM-172	84	150.50	15	27.34	278	18.11	22.41	26.38	11.49	70.93	63.58	56.46	149.25	3.48
33	GM-173	86	149.00	15	26.62	315	28.28	24.06	25.51	11.84	64.91	60.32	53.88	174.25	3.30
34	GM-175	81	160.50	14	30.54	224	25.14	22.84	24.95	12.68	75.14	70.72	62.00	180.50	3.61
35	GM-178	79	141.00	15	31.59	226	15.57	24.79	25.32	11.56	80.88	72.31	61.26	125.25	4.25
36	MTU 7029©	119	92.50	14	28.22	225	23.58	20.13	19.25	6.95	76.57	66.92	63.53	181.25	4.37
37	BPT 5204©	110	94.00	14	26.64	243	21.86	13.89	20.36	7.99	77.13	66.09	61.24	173.00	4.65
	Minimum	66	93	11	21.59	189	14.59	13.89	19.25	6.95	64.91	57.98	53.88	115.25	3.04
	Maximum	119	170	16	32.71	321	29.09	24.79	35.77	15.92	82.13	74.84	64.53	181.25	4.65
Range		76	139.92	13.74	26.42	246	20.48	21.59	27.07	11.46	75.04	67.40	59.20	145.96	3.56
Mean		0.69	1.03	1.08	0.65	3.26	0.81	0.86	0.58	0.4	0.85	0.77	0.88	1.65	0.04
SEM		1.99	2.97	2.99	1.88	9.39	2.35	2.50	1.67	1.17	2.37	2.12	2.54	3.25	0.13
CD (0.05)		1.27	1.94	11.00	3.50	1.87	5.64	5.68	3.04	5.02	1.55	1.61	2.10	1.10	1.80
CV (%)															

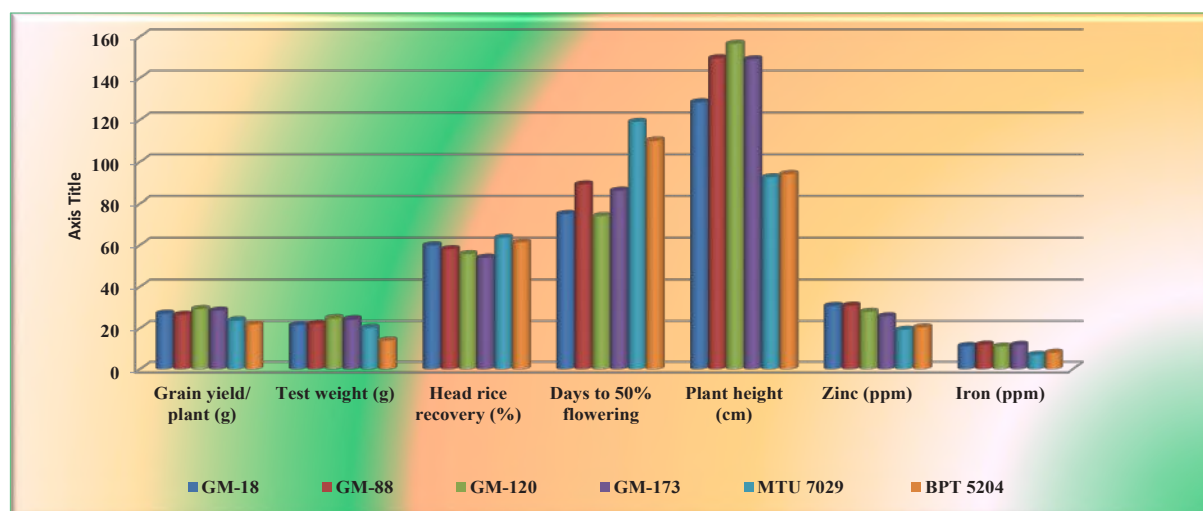


Fig. 1. Promising Zinc rich landraces

Table 3. Promising zinc- rich landraces identified in the study

S.No	Zinc rich landraces	Grain yield/plant (g)	Test weight (g)	Head rice recovery (%)	Days to 50% flowering	Plant height (cm)	Zinc (ppm)	Iron (ppm)
Landraces								
1	GM-18	26.80	21.51	59.81	75	128.50	30.59	11.25
2	GM-88	26.24	22.16	57.98	89	149.50	30.73	11.96
3	GM-120	29.06	24.62	55.59	74	156.50	27.69	11.01
4	GM-173	28.28	24.06	53.88	86	149.00	25.51	11.84
Checks								
1	MTU 7029	23.58	20.13	63.53	119	92.50	19.25	6.95
2	BPT 5204	21.86	13.89	61.24	110	94.00	20.36	7.99

Table 4. Component loading of different characters in rice for yield and quality traits

Canonical Roots Analysis (PCA)				
Components	1 Vector	2 Vector	3 Vector	
Eigene Value (Root)	7.24024	2.62036	1.10614	
% Variance	51.71597	18.71688	7.90102	
Cumulative%	51.71597	70.43284	78.33385	
S.No	Characters	PC1	PC2	PC3
1	Days to 50% flowering	0.36432	0.00224	0.08822
2	Plant Height (cm)	-0.31696	0.00563	-0.091
3	Number of productive tillers plant ⁻¹	0.35604	0.00533	0.00704
4	Panicle length (cm)	-0.27687	-0.18411	-0.01459
5	Grains panicle ⁻¹	-0.12429	0.2046	-0.81049
6	Grain yield plant ⁻¹ (g)	-0.10904	0.47412	0.03449
7	Thousand seed weight (g)	-0.26115	-0.21792	0.33063
8	Zinc content (ppm)	-0.34172	-0.002	-0.10989
9	Iron content (ppm)	0.28266	-0.19213	-0.32098
10	Hulling recovery (%)	-0.15509	-0.48254	-0.13813
11	Milling recovery (%)	0.02652	-0.58344	-0.09586
12	Head rice recovery (%)	0.2972	-0.18229	-0.23091
13	Water uptake (ml)	0.27147	-0.02941	0.13409
14	Volume expansion ratio	0.29051	0.08745	-0.04007

Table 5. PCA scores for Zinc-rich rice landraces

S.No.	Genotype	PCA I X Vector	PCA II Y Vector	PCA III Z Vector
1	GM -7	60.727	-47.539	-33.591
2	GM -12	61.679	-45.316	-35.891
3	GM -16	53.093	-39.269	-36.365
4	GM -17	54.409	-42.466	-39.073
5	GM -18	52.884	-39.222	-35.384
6	GM -22	52.708	-48.06	-37.878
7	GM -32	64.249	-47.538	-32.807
8	GM -42	57.344	-42.159	-33.56
9	GM -44	56.233	-43.323	-32.207
10	GM -79	64.208	-53.372	-31.514
11	GM -80	62.254	-52.575	-35.537
12	GM -86	51.157	-42.2	-38.537
13	GM -87	52.408	-50.593	-40.094
14	GM -88	57.542	-39.313	-38.901
15	GM -91	56.4	-53.217	-39.37
16	GM -93	57.709	-45.847	-39.087
17	GM -94	56.89	-46.076	-35.106
18	GM -117	55.354	-48.749	-32.287
19	GM -120	50.556	-30.28	-38.011
20	GM -122	51.421	-39.86	-43.399
21	GM -124	61.618	-45.915	-41.792
22	GM -125	65.342	-45.646	-31.018
23	GM -127	48.584	-46.903	-33.592
24	GM -128	55.471	-46.504	-37.965
25	GM -129	57.874	-46.702	-44.676
26	GM -155	57.889	-49.146	-40.058
27	GM -156	57.13	-45.312	-40.583
28	GM -157	58.111	-47.313	-41.49
29	GM -163	57.246	-42.816	-47.008
30	GM -167	68.455	-49.555	-46.69
31	GM -169	64.342	-44.585	-38.827
32	GM -172	58.52	-41.137	-40.279
33	GM -173	71.572	-34.435	-39.895
34	GM -175	65.285	-47.186	-36.454
35	GM -178	71.439	-52.872	-37.723
36	MTU-7029©	109.333	-45.96	-28.403
37	BPT-5204©	104.354	-43.651	-32.271

Table 6. Clustering pattern of zinc rich landraces in rice

Clusters	Number of Genotypes	List of Genotypes
1	5	GM-16, GM-18, GM-88, GM-120 and GM-122
2	8	GM-32, GM-79, GM-80, GM-125, GM-167, GM-169, GM-175 and GM-178
3	6	GM-22, GM-87, GM-91, GM-117, GM-128 and GM-155
4	3	GM-17, GM-86 and GM-127
5	12	GM-7, GM-12, GM-42, GM-44, GM-93, GM-94, GM-124, GM-129, GM-156, GM-157, GM-163 and GM-172
6	1	GM-173
7	2	MTU-7029 and BPT-5204

Table 7. Cluster mean values in PCA for yield and quality traits in rice

Clusters	Days to 50% flowering	Plant height (cm)	Number of productive tillers plant ⁻¹	Panicle length (cm)	Grains panicle ⁻¹	Grain yield / plant (g)	Thousand seed weight (g)	Zinc content (ppm)	Iron content (ppm)	Hulling recovery percent	Milling recovery percent	Head rice recovery	Water Uptake (ml)	Volume expansion ratio
1	70.700	144.800	13.300	24.643	263.300	25.645	23.210	28.572	10.825	70.991	63.605	56.316	125.800	3.414
2	67.563	149.625	14.063	29.958	228.125	15.735	24.556	26.923	11.701	76.098	68.991	59.086	156.750	3.621
3	65.167	139.333	13.000	25.329	239.250	14.643	25.923	27.086	11.782	79.793	71.747	58.398	148.833	3.356
4	72.333	144.333	12.667	26.358	231.167	18.255	22.715	30.068	11.055	75.295	66.845	58.257	133.167	3.798
5	68.625	138.083	13.333	26.884	252.583	15.872	21.973	27.329	11.692	73.960	67.718	57.512	144.083	3.570
6	80.000	131.833	14.667	26.023	274.167	26.882	24.082	22.470	9.675	72.032	65.395	57.895	181.667	3.928
7	113.750	92.250	13.250	26.618	231.500	23.610	18.425	19.975	7.568	77.548	66.873	62.528	178.750	4.595

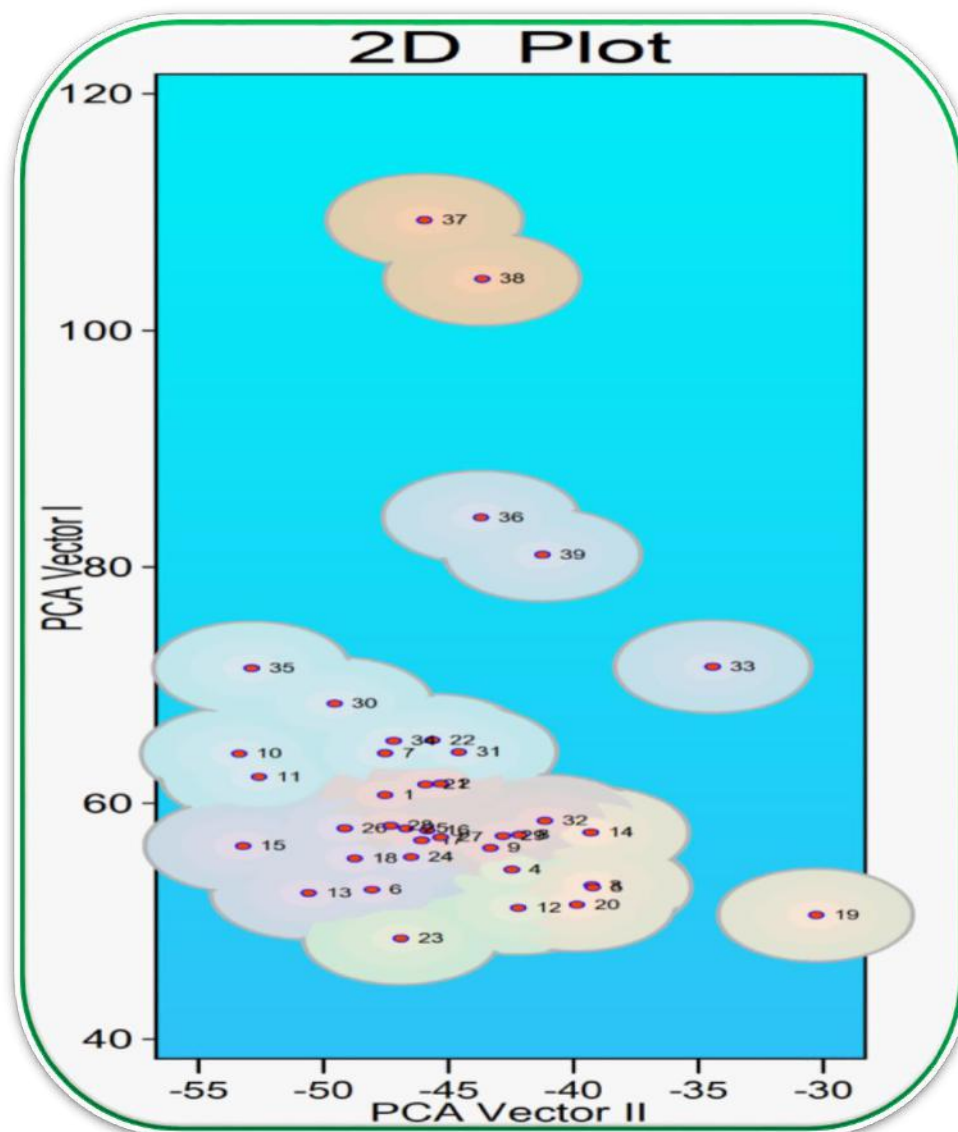


Fig. 2. Two dimensional graph showing relative positions of zinc rich rice landraces based on PCA score

for test weight; Christina *et al.* (2021) for productive tillers; Singh *et al.* (2020) for hulling recovery and head rice recovery (%) and grains panicle⁻¹ for Kumari *et al.* (2021). The PCA scores for zinc-rich rice landraces in the first three principal components were computed and were considered as three axes X, Y, and Z, and the squared distance of each genotype from these three axes was calculated. The results on PCA scores of the landraces for the three principal components are presented in **Table 5**. The PCA scores of zinc-rich rice landraces were also plotted in a graph to get a two-dimensional scatter diagram presented in **Fig. 2**. The land races under study were grouped into seven clusters (**Table 6**). Among these clusters, cluster VII had two genotypes *i.e* MTU 7029 and BPT 5204 (**Table 7**), while cluster IV had three genotypes such as GM-17, GM-86 and GM-127 with greater mean for grain zinc content (30.06 ppm) and cluster VI had one genotype (GM-173) with high mean for the number of productive tillers plant⁻¹ (14.66), grain yield plant⁻¹ (26.88g), and water uptake (181.66 ml). Hence, the selection of landraces from these clusters could be useful in the development of the high yielding and nutrient rich rice varieties

Based on the study, the landraces GM-173 and GM-120 have been identified to be genetically diverse, high yielding and nutrient rich. These genotypes could be exploited in rice bio-fortification programs.

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