Biological Forum – An International Journal 16(4): 96-100(2024)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Evaluation of Iron Tolerance in Indigenous Rice (*Oryza sativa* L.) Genotypes of Eastern Himalaya Region

Chamin Chimyang*[1]*, E.V. Divakar Sastry*[1]*, Dawa Dolma Bhutia*[2] *and N. Anthony Baite*[3]**

[1]*Department of Genetics and Plant Breeding,*
Central Agricultural University, Imphal (Manipur), India.
[2]*Department of Mycology and Plant Pathology, Institute of Agricultural Sciences,*
Banaras Hindu University, Varanasi (Uttar Pradesh), India.
[3]*Department of Agronomy, Institute of Agricultural Sciences,*
Banaras Hindu University, Varanasi (Uttar Pradesh), India.

(Corresponding author: N. Anthony Baite)*
(Received: 13 February 2024; Revised: 25 February 2024; Accepted: 14 March 2024; Published: 15 April 2024)
(Published by Research Trend)

ABSTRACT: In regions characterized by high rainfall, iron toxicity presents a significant challenge to rice cultivation, impacting crop health and productivity. This study conducted in College of Agriculture, Central Agricultural University, Imphal, focuses on assessing the iron toxicity tolerance of 17 rice genotypes, aiming to identify cultivars suitable for cultivation under iron toxicity. Five levels of iron (0, 300, 600, 900 and 1200 mg/L Fe^{2+}) were tested through controlled experimentation, simulating conditions typical of iron toxicity, the genotypes were evaluated for their response to varying levels of Fe^{2+}. Results reveal substantial genotype-specific variations in iron toxicity tolerance, with certain cultivars exhibiting resilience to elevated iron levels while others demonstrate increased susceptibility.

Keywords: Fe^{2+} toxicity, Rice genotypes, tolerance.

INTRODUCTION

In the eastern Himalayan region, where rice cultivation is integral to agricultural practices and livelihoods, understanding the nuances of rice plant responses to various environmental factors is crucial for ensuring sustainable crop production and food security (Baishya *et al.,* 2015). Among these factors, the influence of iron (Fe^{2+}) levels on rice growth and development has garnered significant attention due to its potential impact on yield and crop health (Butsai *et al.,* 2022). Iron, an essential micronutrient for plants, plays a vital role in various physiological processes, including chlorophyll synthesis, photosynthesis, and enzyme activities (Rout and Sahoo 2015). In the context of Eastern Himalayan region, which is characterized by high rainfall (Deka *et al*., 2016) the soil is replaced by hydrogen ions (H^+). Soil acidity increases with the buildup of H^+ and Al^{3+} or with the leaching out of bases cations such as potassium (K^+), calcium (Ca^{2+}) etc., and replaced by H^+ (Agegnehu *et al*., 2021). This excessive levels of iron in the soil can lead to toxicity, adversely affecting plant growth, nutrient uptake, and ultimately, yield (Zahra *et al*., 2021). Therefore, recognising available genotypes within the region, tolerant to Fe toxicity, pose as one of the cost-effective managements for problem soil.

MATERIAL AND METHODS

The study was conducted in Department of Genetics and Plant Breeding, College of Agriculture, Central Agriculture University, Imphal during 2021, to screen the genotype response towards iron toxicity. The experiment was conducted in Randomized Block Design (RBD), with 17 rice genotypes (Table 1) subjected to 5 levels of Fe^{2+} (0, 300, 600, 900 and 1200 mg/L Fe^{2+}) and replicated thrice. Ferrous Sulphate heptahydrate ($FeSO_4.7H_2O$) was used as a source of Fe^{2+}. The experiment was conducted in a hydroponic system and the growth chamber was set at 26°C with16/8 light/dark hour duration. Yoshida solution was prepared using the standard procedure as described by Yoshida *et al.* (1976) and was supplemented to rice along with different levels of iron on every alternate day. Data on germination percentage was recorded on the 7th Day after sowing (DAS), whereas shoot length, shoot dry weight, root length, root dry weight was recorded after 14 DAS. Standard procedures were followed for recording of data and visual scoring of iron-toxicity symptoms was done in accordance with Standard Evaluation System (SES) of rice (IRRI, 1996).

Table 1: List of rice genotypes used for the experiment.

Genotype	Name	Genotype	Name
G1	Chamyak	G10	Lahi emmo
G2	Chasa low land	G11	Lailo
G3	Chasa upland	G12	Lal dhan
G4	Damdaamo	G13	Local basmati (Doimukh)
G5	Deku	G14	Pasighat
G6	Gaksum	G15	Pikhi
G7	Geturaj	G16	Simoi
G8	Itanaghar	G17	Twisa
G9	Kala Joha		

RESULTS AND DISCUSSION

A. Root count

Mean value of root count of all the genotypes has been presented in Fig. 1. The highest mean value for root count under control was found in Local basmati (15.33) while the least root count was found in Geturaj and Lahi emmo (7.33). Under 300mg/L Fe^{2+}, Local basmati (10.33) was least affected while Geturaj (4.00) was much affected. Under 600 mg/L Fe^{2+}, Lal dhan and Local basmati (7.00) was least affected while much effect of iron stress was seen in Geturaj (3.33). Under 900mg/L Fe^{2+} stress level of iron, Local basmati (4.66) was least affected while Geturaj (1.33) was much affected. And in the last treatment, 1200mg/L Fe^{2+}, Local basmati and Pikhi (2.33) was least affected while Lailo and Twisa (0.66) was much affected by the stress level for the concerned genotype.

B. Germination percentage

Data on germination percentage is presented in Table 3. Among the genotypes, Pasighat was not affected by the iron stress exhibiting cent percent germination at each level of stress, while Lailo has shown linear reduction along the stress levels, indicating its sensitivity to iron stress. This genotype also registered lowest germination percentage (66.66%) among the genotypes. This was followed by Twisa which also registered lower germination percentage at extreme iron stress while showing linear reduction along the stress. Deku, Gaksum, Kala Joha, Lahi emmo and Pasighat on the other hand have exhibited lower germination at higher stress only. While upto 900mg/L Fe^{2+} there was no to little reduction in germination.

C. Shoot length

Data on shoot length as given in Table 3 shows that, in control, the highest root length was observed in Local Basmati (22.68 cm), while the lowest shoot length was observed in Lailo (14.35 cm). In stress of 300mg/L Fe^{2+}, least affected genotype was Local Basmati (16.48 cm) while the most affected genotype was Lailo (10.35 cm). In stress of 600mg/L Fe^{2+}, the most affected genotype was Lailo (7.18 cm) while the least affected genotype was Kala Joha (12.14 cm). In stress of 900mg/L Fe^{2+}, most affected genotype was Twisa (5.54 cm) while the least affected genotype was Kala joha (10.61 cm). In stress of 1200mg/L Fe^{2+}, the most affected genotypes were Lailo and Twisa (2.81cm) while the least affected genotype was Gaksum (5.76 cm).

D. Shoot dry weight

Mean value of shoot dry weight is given in Table 3. Highest shoot dry weight under control was observed in Pasighat (0.804g) and the least was observed in Chasa upland (0.39g). In stress condition of 300mg/L Fe^{2+}, the least reduction in shoot weight was found in Damda Aamo (0.69 g) while the most reduced under the same stress level was found in Pikhi (0.26g). The pattern of least reduced was observed in Pasighat under stress level of 600mg/L Fe^{2+} (0.43g), as well as in 900mg/L Fe^{2+} (0.33g) and 1200mg/L Fe^{2+} (0.017g). While for the most reduced shoot fresh weight was observed in Pikhi, and Chasa upland at 600mg/L Fe^{2+} (0.020g); chasa upland, Lailo and Twisaat and 900mg/L Fe^{2+} (0.11g), while in 1200mg/L Fe^{2+} most reduction in shoot fresh weight was observed in Twisa (0.005g).

E. Root length

Data on root length as presented in Table 4 suggests that the highest root length in control treatment was that of Local basmati (14.71 cm) while the shortest root length was observed in Chasa (upland) (7.43 cm). In stress of 300 mg/L Fe^{2+}, the least affected genotype was Gaksum (11.38 cm) while the most affected genotype was Chasa (upland) (5.28 cm). In stress condition of 600mg/L Fe^{2+}, the least affected genotype was Gaksum (7.48 cm) while the most affected genotype was Lailo (3.63 cm). In stress condition of 900mg/L Fe^{2+}, Gaksum was least affected (5.53 cm) while Lailo was the most affected genotype (2.00 cm). In stress condition of 1200mg/L Fe^{2+}, Gaksum showed more tolerance to stress (3.61 cm) while the most affected genotype was Simoi (0.91 cm).

F. Root dry weight

Mean value of root dry weight is given in Table 4. Under control treatment, the highest dry weight was observed in Damdaaamo (0.070g), while the least was recorded in Chasa upland (0.025g). For 300 mg/L Fe^{2+} application, the highest (0.050g) was recorded in pasighat and the lowest (0.016g) shared by Chasa upland and Twisa. At application of 600 mg/L Fe^{2+}, Damdaaamo and Pasighat displayed the highest dry weight (0.033g), while Lailo and Twisa shared the lowest recorded root dry weight (0.011g). Under 900 mg/L Fe^{2+} application, Pasighat displayed the highest value (0.021g) and chasa upland, Lailo and Simoi showed the lowest value (0.006g). At 1200 mg/L Fe^{2+} application, Chamyak showed the highest root dry weight (8.43g) and Simoi and Twisa displayed the least dry weight (0.430g).

G. Leaf Score Index

From data on leaf score index (Table 4), it is evident that the highest mean value under 300mg/L Fe^{2+} stress level of iron was found in Chasa lowland, Kala joha and Lailo (1.81) indicating that these genotypes showed more symptoms of iron stress while Lahi emmo (1.09) under the same stress condition showed less symptoms of iron stress. Mean value of leaf score was observed high in Chasa lowland, Damda Aamo and Pikhi (2.34) under the stress condition of 600mg/L Fe^{2+} indicating that these genotypes were much more affected by stress level of iron while least leaf score was found in Gaksum, Local basmati and Simoi (1.44) indicating that these genotypes were least affected by the iron toxicity. Mean value was found high in Kala joha (2.73) under the iron stress of 900mg/L Fe^{2+} indicating that genotype is much affected by iron toxicity while Gaksum (2.02) was least affected by iron toxicity. Under iron stress of 1200mg/L Fe^{2+}, high mean value was seen in Chasa upland, Kala Joha and Simoi (2.85) indicating that these genotypes were very much affected by iron toxicity; while Chamyak, Damdaaamo, Gaksum, Geturaj, Lahi emmo, Local basmati, Pikhi (2.6) genotypes showed least symptoms to iron toxicity indicating that iron stress had less impact on these genotypes.

H. Analysis of Variance:

The pooled ANOVA implied that there were significant differences among the genotypes as shown in Table 2. The sum of squares due to iron levels was found to be significant for all the characters implying that the genotypes were affected by iron levels. Except for leaf score index (LSI), significant differences for the interaction between iron and genotypes were also observed indicating that the genotypes have not responded linearly to the changing iron stress, *i.e.*, differential response of the genotypes to the iron stress was observed. The findings were closely similar to prior works done by Jahan *et al*. (2016); Dufey *et al.* (2009).

I. Correlation

All the parameters studied under the experiment, such as shoot length, root length, shoot dry weight and root dry weight has high significant positive correlation with each other; while all the above-mentioned characters are negatively correlated to leaf score index. The results were found to be closely similar with Amaranatha (2016); Joseph (2015).

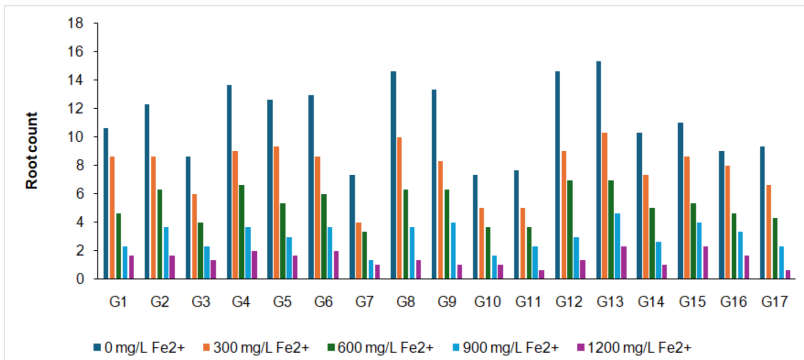

Fig. 1. Effect of iron toxicity on number of roots.

Table 2: Pooled analysis of variance for seedling character at different levels of iron concentration.

SV	DF	GP	SL	RL	SFW	RFW	SDW	RDW	RC	LSI
Replication	2	161.57*	9.61***	1.59***	0.029**	0.0039**	0.000020	0.00003*	3.28	1.71***
Iron levels (I)	4	934.31***	1663.28***	462.11**	0.90***	0.06***	0.02***	0.01***	770.65***	32.18***
Genotypes (G)	16	188.77***	32.32***	27.07***	0.07***	0.04***	0.0009***	0.0007***	27.13***	0.23**
I × G	64	34.73	2.37**	2.01***	0.004***	0.002***	0.00009***	0.00008***	3.08**	0.09
Pooled error	168	52.44	1.33	0.19	0.009	0.0007	0.00001	0.000006	1.82	0.10

Table 3: Effect of iron concentration on germination percentage, shoot length and shoot dry weight of different genotypes.

Genotype	Germination percentage (%)					Shoot length (cm)					Shoot dry weight (g)				
	Mg/L Fe^{2+}					Mg/L Fe^{2+}					Mg/L Fe^{2+}				
	0	300	600	900	1200	0	300	600	900	1200	0	300	600	900	1200
G1	100	100	96.66	96.66	86.66	18.08	13.50	9.51	6.62	4.43	0.054	0.043	0.028	0.018	0.011
G2	100	100	93.33	93.33	90.00	19.71	15.93	10.60	7.33	4.95	0.049	0.036	0.025	0.014	0.009
G3	100	96.66	96.66	93.33	96.66	15.78	12.16	7.66	5.36	3.00	0.039	0.026	0.020	0.011	0.008
G4	100	96.66	96.66	96.66	93.33	20.81	15.68	10.20	7.68	4.86	0.090	0.069	0.044	0.025	0.014
G5	100	100	100	93.333	90.00	19.04	15.45	9.43	6.73	4.68	0.056	0.048	0.028	0.017	0.011
G6	100	100	96.66	96.66	90.00	22.13	15.86	11.13	8.38	5.76	0.062	0.047	0.031	0.023	0.013
G7	100	100	100	93.33	86.66	17.21	13.31	8.93	6.49	3.81	0.055	0.039	0.028	0.015	0.009
G8	100	100	100	100	96.66	18.58	15.13	8.86	6.39	4.35	0.068	0.057	0.036	0.027	0.014
G9	100	100	96.66	93.33	96.66	20.13	15.60	12.14	10.61	5.21	0.060	0.043	0.030	0.025	0.012
G10	100	100	100	100	90.00	17.94	13.60	9.60	6.98	4.65	0.057	0.044	0.029	0.029	0.010
G11	100	93.33	83.33	76.66	66.66	14.35	10.35	7.18	5.57	2.81	0.051	0.027	0.030	0.011	0.008
G12	100	96.66	96.66	93.33	86.66	18.80	15.83	9.81	6.46	4.40	0.050	0.040	0.027	0.016	0.011
G13	100	100	100	90.00	90.00	22.68	16.48	11.45	8.52	5.43	0.080	0.057	0.039	0.024	0.011
G14	100	100	100	100	100	21.15	15.13	9.70	7.28	4.58	0.080	0.063	0.043	0.033	0.017
G15	100	100	96.66	90.00	86.66	17.76	15.16	8.85	6.54	4.21	0.041	0.030	0.020	0.014	0.011
G16	100	96.66	93.33	90.00	86.66	15.66	12.01	8.01	5.82	2.93	0.051	0.038	0.026	0.013	0.006
G17	100	96.66	90.00	86.66	86.66	15.10	12.23	8.26	5.54	2.81	0.051	0.037	0.029	0.011	0.005
Sem	**-**	**1.97**	**4.08**	**4.42**	**6.47**	**0.44**	**0.57**	**0.36**	**0.33**	**0.35**	**0.002**	**0.002**	**0.001**	**0.003**	**0.001**
C.D	**NS**	**NS**	**NS**	**NS**	**NS**	**1.27**	**1.65**	**1.05**	**0.96**	**1.01**	**0.008**	**0.006**	**0.003**	**0.009**	**0.003**

Table 4: Effect of iron concentration on root length, root dry weight and leaf score index of different genotypes.

Genotype	Root length (cm)					Root dry weight (g)					Leaf score index				
	Mg/L Fe^{2+}					Mg/L Fe^{2+}					Mg/L Fe^{2+}				
	0	300	600	900	1200	0	300	600	900	1200	0	300	600	900	1200
G1	8.30	5.71	4.16	2.85	1.53	0.036	0.027	0.018	0.011	8.430	0.70	1.42	2.18	2.6	2.60
G2	8.68	5.68	4.20	2.91	1.73	0.038	0.025	0.015	0.007	1.000	0.70	1.81	2.34	2.47	2.72
G3	7.43	5.28	3.93	2.26	1.06	0.025	0.016	0.012	0.006	0.460	0.70	1.44	2.18	2.6	2.85
G4	13.28	10.30	6.68	4.80	3.31	0.070	0.047	0.033	0.016	5.630	0.70	1.25	2.34	2.47	2.60
G5	8.60	6.18	4.38	2.51	1.80	0.029	0.020	0.015	0.012	8.200	0.70	1.42	1.81	2.18	2.31
G6	14.48	11.38	7.48	5.53	3.61	0.040	0.034	0.021	0.011	6.430	0.70	1.44	1.44	2.02	2.60
G7	8.55	5.93	4.56	2.83	1.56	0.038	0.025	0.018	0.009	0.800	0.70	1.44	1.81	2.31	2.60
G8	8.40	6.31	4.58	4.10	2.48	0.045	0.032	0.022	0.015	5.800	0.70	1.25	1.97	2.60	2.73
G9	9.20	6.83	4.90	3.85	2.00	0.039	0.026	0.021	0.012	5.900	0.70	1.81	2.18	2.73	2.85
G10	8.90	6.63	4.73	2.90	1.96	0.037	0.027	0.019	0.009	4.500	0.70	1.09	2.02	2.60	2.60
G11	7.70	5.75	3.63	2.00	1.05	0.028	0.017	0.011	0.006	0.500	0.70	1.81	2.02	2.60	2.72
G12	8.88	5.93	4.68	3.00	1.70	0.031	0.027	0.015	0.009	1.430	0.70	1.65	2.18	2.60	2.72
G13	14.71	9.28	6.33	3.53	1.43	0.060	0.041	0.030	0.014	5.930	0.70	1.22	1.44	2.47	2.60
G14	10.6	7.56	6.06	4.85	2.48	0.067	0.050	0.033	0.021	5.730	0.70	1.26	1.81	2.34	2.47
G15	8.26	6.21	3.93	2.91	1.81	0.029	0.021	0.014	0.007	0.830	0.70	1.59	2.34	2.47	2.60
G16	7.80	5.65	4.15	2.18	0.91	0.033	0.018	0.012	0.006	0.430	0.70	1.44	1.44	2.47	2.85
G17	7.53	5.43	3.80	2.15	1.00	0.030	0.016	0.011	0.007	0.430	0.70	1.65	2.02	2.60	2.72
Sem	**0.29**	**0.32**	**0.36**	**0.18**	**0.15**	**0.0018**	**0.0017**	**0.0009**	**0.0011**	**0.0011**	**-**	**-**	**0.70**	**-**	**-**
C.D	**0.84**	**0.93**	**1.06**	**0.49**	**0.46**	**0.0053**	**0.0048**	**0.0027**	**0.0033**	**0.0030**	**NS**	**NS**	**2.04**	**NS**	**NS**

Table 5: Correlation analysis.

	Iron levels	Shoot length	Root length	Shoot dry weight	Root dry weight	Root count	Leaf score index
Germination percentage	[1]Control	-	-	-	-	-	-
	[2]300mg/L Fe^{2+}	-	-	-	-	-	-
	600mg/L Fe^{2+}	0.30*	0.25	0.16	0.33*	0.09	-0.09
	900mg/L Fe^{2+}	0.22	0.37**	0.35*	0.38**	0.09	-0.13
	1200mg/L Fe^{2+}	0.23	0.27	0.36**	0.23	-0.01	-0.15
Shoot length	Control		0.78***	0.63***	0.66***	0.59***	-
	300mg/L Fe^{2+}		0.46***	0.50***	0.53***	0.57***	-0.22
	600mg/L Fe^{2+}		0.69***	0.37**	0.57***	0.58***	-0.12
	900mg/L Fe^{2+}		0.66***	0.43*	0.44**	0.40**	-0.18
	1200mg/L Fe^{2+}		0.62***	0.53***	0.47***	0.26	-0.16
Root length	Control			0.71***	0.69***	0.42***	-
	300mg/L Fe^{2+}			0.61***	0.68***	0.32*	-0.16
	600mg/L Fe^{2+}			0.67***	0.75***	0.41**	-0.30*
	900mg/L Fe^{2+}			0.63***	0.67***	0.39**	-0.26
	1200mg/L Fe^{2+}			0.68***	0.42**	0.24	-0.22
Shoot dry weight	Control				0.90***	0.37**	-
	300mg/L Fe^{2+}				0.84***	0.38**	-0.27
	600mg/L Fe^{2+}				0.86***	0.32*	-0.17
	900mg/L Fe^{2+}				0.61***	0.18	-0.15
	1200mg/L Fe^{2+}				0.51***	0.25	-0.24
Root dry weight	Control					0.31*	-
	300mg/L Fe^{2+}					0.28*	-0.25
	600mg/L Fe^{2+}					0.40**	-0.09
	900mg/L Fe^{2+}					0.24	-0.11
	1200mg/L Fe^{2+}					0.09	-0.36*
Root count	Control						-
	300mg/L Fe^{2+}						0.04
	600mg/L Fe^{2+}						0.00
	900mg/L Fe^{2+}						-0.07
	1200mg/L Fe^{2+}						-0.02

[1]Since there was no variation found in all the traits in iron level of control (0mg/L $Fe2^{+}$)
[2]Since there was no variation found for all the traits in iron level of 300mg/L $Fe2^{+}$)
***Significant at 0.1% level**Significant at 1% level*Significant at 5% level

CONCLUSIONS

Based on the findings of the experiment, It was observed that genotypes such as Local basmati, Pasighat, Damda Aamo, Gaksum showed tolerance to varied levels of iron stress while Chasa upland, Lailo, Simoi and Twisa showed susceptibility towards increased levels of iron stress. The experiment also showed that upland rice genotypes are sensitive to iron toxicity as compared to lowland rice genotypes. The experiment can be conducted in field also for further confirmation and to check yield of the crop.

FUTURE SCOPE

The future scope of research in iron toxicity tolerance of rice genotypes holds promise for advancing sustainable rice cultivation practices. By integrating multidisciplinary approaches encompassing genetics, physiology, and agronomy, we can accelerate the development and deployment of resilient rice varieties, thereby enhancing food security and livelihoods in iron-toxic regions.

Acknowledgement. I would like to express my heartfelt gratitude to the department of Genetics and Plant Breeding, Central Agricultural University, as well as to Dr. E.V.D. Sastry (Supervisor), and my advisory committee for granting me the opportunity to carry out my research and for their unwavering guidance throughout the duration of my study.
Conflict of Interest. None.

REFERENCES

Agegnehu, G., Amede, T., Erkossa, T., Yirga, C., Henry, C., Tyler, R., Nosworthy, M. G., Beyene, S. and Sileshi, G. W. (2021). Extent and management of acid soils for sustainable crop production system in the tropical agroecosystems: a review. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science*, *71*(9), 852–869.

Amaranatha, R. M. (2016). Identification of molecular markers linked to iron toxicity tolerance through bulk segregant analysis (BSA) in rice (*Oryza sativa* L.) (Doctoral dissertation, College of Horticulture, Vellanikkara).

Baishya, L. K., Sarkar, D., Ansari, M. A. and Prakash, N. (2015). Yield, quality and profitability of rice (*Oryza sativa* L.) varieties grown in the eastern Himalayan region of India. *African Journal of Agricultural Research*, *10*(11), 1177-1183.

Butsai, W., Kaewpradit, W., Harrell, D. L. and Polthanee, A. (2022). Effect of Iron Application on Rice Plants in Improving Grain Nutritional Quality in Northeastern of Thailand. *Sustainability*, *14*(23), 15756.

Dufey, I., Hakizimana, P., Draye, X., Lutts, S., and Bertin, P. (2009). QTL mapping for biomass and physiological parameters linked to resistance mechanisms to ferrous iron toxicity in rice. *Euphytica*, *167*(2), 143-160.

International Network for Genetic Evaluation of Rice (IRRI). (1996). *Standard evaluation system for rice*. IRRI, International Rice Research Institute.

Jahan, N., Fauzi, N., Javed, M. A., Khan, S., and Hanapi, S. Z. (2016). Effects of ferrous toxicity on seedling traits and Ion Distribution pattern in Upland and Low Land Rice under hydroponic conditions. *Jurnal Teknologi*, *78*(1-2), 39-43.

Joseph, T. (2015). Combining ability for tolerance to iron toxicity in rice (*Oryza sativa* L.) (Doctoral dissertation, Department of plant breeding and genetics, College of horticulture, Vellanikkara).

Rout, G. R. and Sahoo, S. (2015). Role of iron in plant growth and metabolism. *Reviews in Agricultural Sciences*, *3,* 1-2.

Yoshida, S., Forno, D. A., Cock, J. H., and Gomez, K. A. (1976). *Laboratory manual for physiological studies of rice*. IRRI, Las Banos, Laguna.

Zahra, N., Hafeez, M. B., Shaukat, K., Wahid, A. and Hasanuzzaman, M. (2021). Fe toxicity in plants: Impacts and remediation. *Physiologia plantarum*, *173*(1), 201-222.

How to cite this article: Chamin Chimyang, E.V. Divakar Sastry, Dawa Dolma Bhutia and N. Anthony Baite (2024). Evaluation of Iron Tolerance in Indigenous Rice (*Oryza sativa* L.) Genotypes of Eastern Himalaya Region. *Biological Forum – An International Journal, 16*(4): 96-100.