



Genetic Assessment of Germplasms for Anaerobic Germination in Rice

Ramya Rathod ^{a++*}, Akula Dinesh ^{a++}, M. Sreedhar ^{b#},
Sai Charan M ^{at}, Basavaraj PS ^{c++} and S. Vanisri ^{d‡}

^a Regional Sugarcane and Rice Research Station, PJTSAU, Rudrur, Nizamabad, Telangana, 503 188, India.

^b Administrative Office, Professor Jayashankar Telangana State Agriculture University, Rajendranagar, Hyderabad, Telangana, 500 030, India.

^c ICAR-National Institute of Abiotic Stress Management, Baramati, Maharashtra, 413 115, India.

^d Regional Agricultural Research Station (RARS), Palem, Telangana, 509 215, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJSSPN/2024/v10i1233

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/112497>

Original Research Article

Received: 24/11/2023
Accepted: 28/01/2024
Published: 29/02/2024

ABSTRACT

The present study was planned using portray method to screen rice germplasm lines for anaerobic germination (AG) by assessing seedling parameters. Among 266 lines studies, 121 exhibited variable germination % of 100–17 under AG condition. Germplasm lines viz., RDR 7555, WGL 915, CSR 27, RGP 103, IRTON 103, IET 23993, RGP 60 and MTU NS1 were with highest germination capability (100%). Longest seedling length was recorded in WGL 915 (33.1 cm), RGP 57 (31.8 cm) and CSR 27 (31.2 cm). Seedling vigour index was maximum in lines WGL 915 (3310), RGP 57 (3180) and CSR 27 (3120). Genotypes CSR 27 (22.5 cm), WGL 915 (23.3 cm), RGP 57 (23.1 cm),

⁺⁺Scientist (Plant Breeding);

[#] Director of Planning and Monitoring Cell;

[†]Scientist (Entomology);

[‡] Principal Scientist (Oil Seeds);

*Corresponding author: Email: ramyarathod.5@gmail.com;

RGP 103 (21.5 cm) and IRTON 103 (20.7 cm) are possessing highest tolerance to AG conditions with elongated shoot length. Highest root length was recorded in WGL 915 (9.8 cm), CSR 27 (8.7 cm), RGP 57 (8.7 cm), Indursamba (8.5 cm) and RGP 103 (8.1 cm). Highest heritability, genetic advance, PCV and GCV were recorded for seedling vigour index clearly highlights the importance of trait for simple selection. Highest significant positive correlation was observed between the seedling length and seedling vigour index (0.93**) followed by germination % and seedling vigour index (0.88**). Seedling length and germination % are important traits for seedling establishment in direct seeded rice under AG conditions. The 121 Germplasm lines were grouped into four clusters, cluster 3 and 4 has genotypes with above standard germination % (80%), highest seedling length (33.1–20.3 cm) and high vigour index (3310–2030). Present day task for plant breeders is to identify rice germplasm lines tolerant for anaerobic germination and to introgress the trait into the superior variety for development of rice pre-breeding lines with tolerance to anaerobic conditions and high yield [1].

Keywords: Anaerobic germination; direct-seeded rice; heritability; variability; correlation; cluster analysis.

1. INTRODUCTION

Rice, (*Oryza sativa*) edible starchy cereal grain, about one-half of the world population, including virtually all of East and Southeast Asia, is wholly dependent upon rice as a staple food. More than 90 percent of the world's rice is grown in Asia, principally in China, India, Indonesia, and Bangladesh, with smaller amounts in Japan, Pakistan, and various Southeast Asian nations [2]. Rice provides 30–75% of the total calories to more than 3 billion Asians [2]. Agriculture in India is still dependent on the monsoon rains for irrigating their crops. The Indian economy gains due to good monsoon rains in the country resulting in a good yield of crops. Unplanned floods pose a major constraint in the cultivation of rice worldwide. Flooding during germination and early growth; hampers seed germination and seedling establishment. Therefore, in such flooded conditions anaerobic tolerant rice genotypes only show seed germination and emergence above the water surface [3,4].

The share of water for agriculture is declining very fast because of the increasing population, lowering of the water table, declining water quality, inefficient irrigation systems, competition with non-agricultural sectors [5]. At present, irrigated agriculture accounts for 70% and 90% of total freshwater withdrawal globally and in Asia, respectively. In the major rice-growing Asian countries, per capita water availability reduced by 34-76% between 1950 and 2005, and is likely to decline by 18-88% by 2050 [6]. In Asia, rice is commonly grown by transplanting seedlings into puddled soil, facilitating the easy seedling establishment, and creating anaerobic

conditions to enhance nutrient availability [7], Uma rani et al. 2017). But repeated puddling adversely affects soil physical properties by destroying soil aggregates, reducing permeability in subsurface layers, and forming hard-pans at shallow depths [8-10]. Moreover, puddling and transplanting require a large amount of water and labor, both of which are becoming increasingly scarce and expensive, making rice production less profitable. Also, the drudgery involved in transplanting is of serious concern. Depending on water and labor scarcity, farmers are changing their rice establishment methods from transplanting to direct seeding.

The uniform establishment of a crop is critically dependent on seedling vigour and seedling development [11]. Rice seeds can germinate without oxygen [12,13], unlike other major cereals such as wheat [14,13] oat [14], and barley [13], because it can make its enzyme for starch degradation without oxygen [15]. This trait, called anaerobic germination (AG), can decrease the damage by submergence during germination and is particularly important for rice cultivation. Since, anaerobic germination is associated with faster germination and faster coleoptile elongation due to replacement of aerobic respiration by alcoholic fermentation enzymes as a source of energy [16]. It is an essential adaptation trait for DSR to be successful. Hence, a viable DSR should possess the capacity to germinate anaerobically with enhanced tolerance to flooding during germination and early seedling vigour which will end up with successful crop establishment.

Seed longevity, seedling vigor [17-22] seedling growth and adjustment of carbohydrate

metabolism [23,3,24], fast coleoptile elongation, fast leaf and root development (Hsu and Tung, 2015; Kretschmar et al., 2015), and high carbohydrate reserve of seed (Al-Ani et al., 1985; Raymond et al., 1985; Ella et al., 2011) are some of the mechanisms reported to overcome AG conditions.

2. MATERIALS AND METHODS

2.1 Plant Materials

The seed material consisted of 266 germplasm lines collected all over India. The seeds were obtained from the Plant Breeding section, Professor Jayashankar Telanagan State Agriculture University, Regional Sugarcane and Rice Research Station, Rudrur, Nizamabad, Telangana. Before screening the 266 germplasm lines for anaerobic germination (AG), a laboratory germination test was conducted for all the collected genotypes as per the ISTA [25] procedure.

2.2 Protray Methods

In the shade, a net flooded soil evaluation system was established concerning the IRRI method [26,22]. First, the soil was dried and sieved. The soil was placed in 48 well portrays (each well 5 cm square). The trays were submerged in water and the soil was mixed thoroughly with tweezers to remove all the air. The next day 5 seeds from each germplasm were imbibed at a depth of 2 cm under the soil with the help of tweezers in two replications. The trays were then placed in large zinc trays (20 cm depth) in which water was added to a depth of 10 cm. We maintained and monitored the water level regularly and kept the water depth of 10 cm.

2.3 Data Collection

Data was recorded 20 days after the submergence of the germplasm lines for germination %, seed vigour index (SVI), seedling length, shoot length, root length and number of adventitious roots.

Seedling vigor index was calculated by using the below formula as suggested by Abdul-Baki and Anderson [27] expressed in the whole number.

$$\text{Seedling Vigor Index (SVI)} = \text{Germination (\%)} \times \text{Seedling length (cm)}$$

2.4 Statistical Analysis

Correlation between the seed parameters of the germplasm lines as was carried out following Pearson's correlation coefficient method in R open-source software. The phenotypic and genotypic coefficients of variation (PCV% and GCV%) and heritability was estimated according to the method of Falconer [28] and the genetic advance was computed following the formula suggested by Johnson et al. [29].

3. RESULTS AND DISCUSSION

The key importance to studying rice germplasm lines under anaerobic germination situations is to obtain lines with high seedling vigour for further utilization as donors in direct seeding breeding programme to improve the productivity of rice. Rice can germinate under hypoxic or anoxic conditions, but only tolerant genotypes have the ability of rapid coleoptile elongation and root formation under anaerobic conditions in the field [3]. Among the various adaptive mechanisms, high germination % and seedling length are the major characteristics which in turn are closely associated with seedling vigor, which is the final determinant of the optimum crop establishment under anaerobic conditions.

In the present study, 121 germplasms lines showed germination under anaerobic conditions and were found variability for AG %, seed vigour index (SVI), seedling length, shoot length, root length, and number of adventitious roots among the germplasm lines (Table 1).

3.1 Germination %

Based on the germination % the germplasm lines are categorised into five classes viz., 1 - 20%, 21 - 40%, 41 - 60%, 61 - 80% & 81 - 100% with a frequency distribution of 1.65%, 6.61%, 14.04%, 30.57%, 47.10% respectively as shown in Fig 1. The 121 germplasm lines exhibited variable germination capability of 100 % to 17% under AG conditions with a mean of 74%. Fifty-seven germplasm lines have shown above standard germination % (80%) and these entries are treated as tolerant to AG conditions. RDR 7555, WGL 915, CSR 27, RGP 103, IRTON 103, IET 23993, RGP 60 & MTU NS1 with highest germination capability (100%). These germplasm lines seem to have efficient and rapid water uptake during seed imbibition, better capabilities of breaking starch into simple sugar, and faster

depletion of starch in their germinating seeds which might be attributed to their higher germination in comparison to other germplasm lines. RGP 144 (17%) & WGL 1119 (20%) are showing lowest germination (30%). According to the classification of Manigbas et al. [30] the entries showing germination less than 50% could be considered as susceptible genotypes. In the present study, 15 entries are recorded as susceptible to AG conditions.

3.2 Seedling Length (cm)

The seedling length is divided into 7 classes viz., 1 – 5cm, 6 – 10cm, 11 – 15cm, 16 – 20cm, 21 – 25cm, 26 – 30cm & 31 – 35cm with a frequency distribution of 6.61%, 21.48%, 42.14%, 14.87%, 9.09%, 3.3%, 2.47% respectively as shown in Fig 2. The seedling length varied from 33.1cm to 2.0cm with an average of 14.2cm. Longest seedling length was recorded in WGL 915 (33.1cm), RGP 57 (31.8cm), CSR 27 (31.2cm) and shortest in RGP 144 (2.6cm), WGL 1119 (2.7cm) & DRR Dhan 42 (2.0cm).

3.3 Seedling Vigour Index (SVI)

The seeds exhibiting a higher vigour index are considered more vigorous. Based on the vigour they are divided into seven classes viz., 1 – 500, 501 – 1000, 1001 – 1500, 1501 – 2000, 2001 – 2500, 2501 – 3000, 3001 – 3500 with frequency distribution 16.52%, 33.05%, 24.79%, 12.39%, 7.43%, 3.3%, 2.47% respectively as shown in Fig 3. The seedling vigour index ranged from 3310 to 44 with a mean of 1156. Maximum was observed in lines WGL 915 (3310), RGP 57 (3180), CSR 27 (3120) and minimum in RGP 30 (94), Ravi (64), JGL 21098 (78), WGL 1119 (54) & RGP 144 (44).

3.4 Shoot Length (cm)

In anaerobic conditions coleoptile elongation ability influences crop establishment by enabling the seedlings to come in access to oxygen [31], hence shoot length of seedlings including the coleoptiles is used as a marker to determine anaerobic germination tolerance [32]. This parameter was divided into five classes viz., 1 – 5cm, 6 – 10cm, 11 – 15cm, 16 – 20cm, 21 – 25cm with a frequency distribution of 19.83%, 52.06%, 18.18%, 6.61%, 3.3% respectively as shown in Fig 4. The shoot length varied from 23.3cm to 1.2cm with an average of 9.6cm. CSR 27 (22.5cm), WGL 915 (23.3cm), RGP 57 (23.1cm), RGP 103 (21.5cm), IRTON 103 (20.7cm) are having highest tolerance to AG conditions and JGL 20198 (1.9cm), Ravi (1.8cm), RGP 144 (1.5cm) & WGL 1119 (1.2cm) are highly susceptible to AG situations.

3.5 Root Length (cm)

The root length is classified into five classes viz., 1 – 2cm, 3 – 4cm, 5 – 6cm, 7 – 8cm, 9 – 10cm with a frequency distribution of 14.87%, 41.32%, 30.57%, 12.39%, 0.82% as shown in figure 5. As the seedling elongates to more aerated zones, aerenchyma tissue develops to provide oxygen for the submerged plant parts, especially to roots [14,33]. The average root length 4.67cm was recorded ranging from 9.8cm to 1.0cm. Highest recorded in WGL 915 (9.8cm), CSR 27 (8.7cm), RGP 57 (8.7cm), Indursamba (8.5cm), RGP 103 (8.1cm) & lowest in Ravi (1.0cm), RGP144 (1.1cm), JGL 21098 (1.1cm), RNR 15435 (1.2cm), WGL 1119 (1.5cm), RGP 30 (1.7cm), BM 71 (2.0cm) & DRR Dhan 42 (2.0cm).

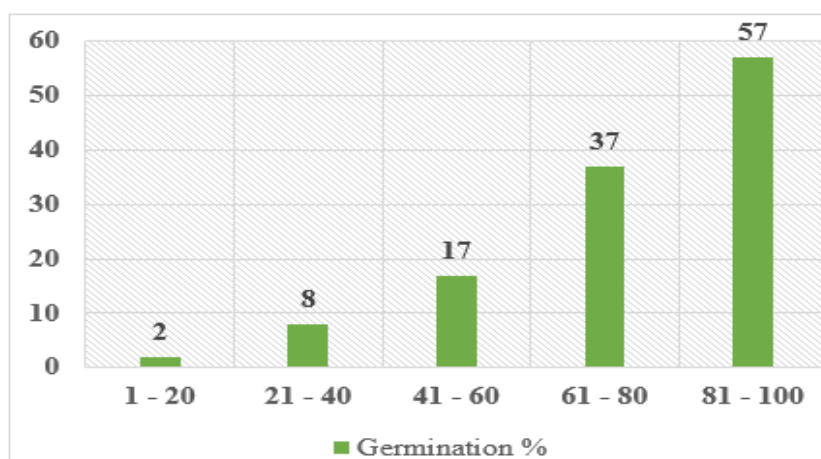


Fig. 1. Frequency distribution of rice germplasm lines for germination %

Table 1. Data of 121 germplasm lines under anaerobic condition

S. No.	Entry Name	Germination Percentage (%)	Seedling Length (cm)	Seedling vigour index (SVI)	Shoot Length (cm)	Root Length (cm)	Adventitious Roots
1	RUDRAMA	100	27.5	2750	20.4	7.1	7.0
2	FV-1	89	14	1246	9.5	4.5	5.0
3	FV-2	76	11.5	874	9.1	2.4	5.0
4	FV-3	96	20.5	1968	15.2	5.3	4.0
5	WGL-44	65	13.3	865	6.4	6.9	5.0
6	WGL-915	100	33.1	3310	23.3	9.8	8.0
7	KNM-118	94	12.6	1184	8.4	4.2	4.0
8	KNM-733	78	12.3	959	8.2	4.1	5.0
9	KNM-1638	64	10.5	672	7.1	3.4	5.0
10	RDR-1199	62	10	620	5.5	4.5	4.0
11	RDR-1200	72	12.9	929	7.8	5.1	4.0
12	INDURSAMBA	82	19.3	1583	10.8	8.5	4.0
13	KPS-2874	79	21.8	1722	15.3	6.5	3.0
14	JGL-24423	82	14.1	1156	8.6	5.5	5.0
15	RNR-15435	27	4.4	119	3.2	1.2	2.0
16	RNR-28361	51	8.9	454	5.4	3.5	3.0
17	RNR-29325	69	10.4	718	6.1	4.3	4.0
18	RNR-15048	38	6.5	247	4.4	2.1	2.0
19	JGL-27356	45	7.4	333	5.2	2.2	4.0
20	WGL-962	71	11.8	838	8.4	3.4	3.0
21	JGL-1798	80	12.9	1032	9.1	3.8	4.0
22	RGP-3	78	12.7	991	8.5	4.2	3.0
23	RGP-10	74	17.2	1273	10.7	6.5	4.0
24	RGP-17	94	19.6	1842	12.7	6.9	4.0
25	RGP-21	61	8.6	525	5.2	3.4	3.0
26	RGP-22	88	16.4	1443	11.3	5.1	6.0
27	RGP-28	81	15.2	1231	9.8	5.4	7.0
28	RGP-30	24	3.9	94	2.2	1.7	1.0
29	RGP-34	83	14.2	1179	9.7	4.5	4.0
30	RGP-40	96	20.7	1987	13.4	7.3	6.0
31	RGP-44	91	16	1456	9.8	6.2	4.0

S. No.	Entry Name	Germination Percentage (%)	Seedling Length (cm)	Seedling vigour index (SVI)	Shoot Length (cm)	Root Length (cm)	Adventitious Roots
32	RGP-53	93	17.5	1628	12.6	4.9	5.0
33	RGP-54	78	14.1	1100	9.5	4.6	4.0
34	RGP-55	95	22	2090	15.5	6.5	4.0
35	RGP-57	100	31.8	3180	23.1	8.7	5.0
36	RGP-58	100	23.5	2350	18.2	5.3	3.0
37	RGP-60	100	24.1	2410	17.4	6.7	8.0
38	RGP-64	93	20.3	1888	13.2	7.1	6.0
39	RGP-7	76	12.5	950	7.3	5.2	3.0
40	RGP-103	100	29.6	2960	21.5	8.1	7.0
41	RGP-99	89	15.9	1415	11.4	4.5	4.0
42	RGP-122	87	12.2	1061	8.7	3.5	6.0
43	RGP-135	82	13.8	1132	10.3	3.5	5.0
44	RGP-153	76	14.6	1110	9.1	5.5	6.0
45	RGP-144	17	2.6	44	1.5	1.1	1.0
46	RGP-159	68	8.6	585	6.5	2.1	5.0
47	RGP-163	79	13.8	1090	8.3	5.5	6.0
48	RGP-167	76	12.8	973	8.5	4.3	5.0
49	JGL-21098	26	3	78	1.9	1.1	1.0
50	JGL-23710	51	14.6	745	9.1	5.5	4.0
51	JGL-13595	57	10.9	621	6.4	4.5	4.0
52	JGL-11727	48	10.3	494	6.2	4.1	4.0
53	JGL-17183	93	24.9	2316	17.5	7.4	6.0
54	JGL-17653	82	8.4	689	7.2	1.2	4.0
55	JGL-18799	61	11.9	726	6.4	5.5	6.0
56	JGL-20621	82	15.6	1279	8.3	7.3	5.0
57	JGL-20141	70	11.8	826	8.4	3.4	5.0
58	JGL-21169	74	10.6	784	8.1	2.5	4.0
59	RNR-2354	92	16.2	1490	11.1	5.1	3.0
60	RNR-15038	86	18.4	1582	11.6	6.8	6.0
61	RNR-19399	94	18.7	1758	13.5	5.2	6.0
62	MTU-1010	84	11.9	1000	8.8	3.1	4.0
63	MTU-1061	84	16.5	1386	10.7	5.8	6.0
64	MTU-1075	63	11	693	5.5	5.5	2.0

S. No.	Entry Name	Germination Percentage (%)	Seedling Length (cm)	Seedling vigour index (SVI)	Shoot Length (cm)	Root Length (cm)	Adventitious Roots
65	MTU-1081	68	10.7	728	7.6	3.1	6.0
66	MTU-1159	91	19.9	1811	13.7	6.2	4.0
67	MTU-NS1	100	21.4	2140	15.1	6.3	4.0
68	MTU/II-2815-01	83	13.4	1112	8.3	5.1	3.0
69	MTU-II-1936-12-14	30	5.7	171	2.5	3.2	3.0
70	NLR-40054	73	12.6	920	7.1	5.5	6.0
71	NLR-3275	81	20.9	1693	13.8	7.1	5.0
72	NLR-40024	97	23.7	2299	16.5	7.2	3.0
73	NLR-3102	93	13.3	1237	9.2	4.1	5.0
74	CSR-13	89	14.3	1273	10.8	3.5	5.0
75	CSR-27	100	31.2	3120	22.5	8.7	4.0
76	CSR-26-49-7	90	14.1	1269	9.5	4.6	6.0
77	GSR-27	65	15.1	982	9.3	5.8	4.0
78	GSR-35	74	9.3	688	7.2	2.1	4.0
79	GSR-326601	98	22.3	2185	15.4	6.9	5.0
80	IRTON-103	100	28.2	2820	20.7	7.5	5.0
81	IRTON-109	92	11.7	1076	8.2	3.5	6.0
82	IRTON-114	83	13.7	1137	8.2	5.5	4.0
83	IRTON-210	74	9.9	733	6.4	3.5	5.0
84	IR-64	81	12.6	1021	9.4	3.2	5.0
85	IR-06-N-183	92	21.2	1950	16.1	5.1	5.0
86	IR-678-25-5	41	9.8	402	4.5	5.3	2.0
87	IR-744371-46-1-1-1	40	8.2	328	4.3	3.9	3.0
88	WGL-482	57	10	570	5.5	4.5	2.0
89	WGL-1125	42	8.1	340	4.4	3.7	5.0
90	WGL-1119	20	2.7	54	1.2	1.5	3.0
91	WGL-1145	43	9.7	417	5.5	4.2	4.0
92	WGL-1558	61	12	732	9.2	2.8	5.0
93	WGL-1131	64	10.6	678	7.4	3.2	3.0
94	HKR-8-62	76	11.8	897	8.3	3.5	4.0
95	HH2-DT-4-41-41	59	12.1	714	4.2	7.9	2.0
96	HAV-3822-79-4-3-4	94	16.1	1513	12.1	4.0	5.0
97	HH2-25-5AL-10D2-DT1	81	12.1	980	7.8	4.3	3.0

S. No.	Entry Name	Germination Percentage (%)	Seedling Length (cm)	Seedling vigour index (SVI)	Shoot Length (cm)	Root Length (cm)	Adventitious Roots
98	JAI SRIRAM	80	14.9	1192	9.9	5.0	4.0
99	SUMATHI	68	7.7	524	5.2	2.5	4.0
100	RAVI	23	2.8	64	1.8	1.0	1.0
101	GORIYA	63	13.1	825	9.1	4.0	5.0
102	TRIGUNA	91	14	1274	10.5	3.5	5.0
103	PUSA-44	75	12.5	938	8.3	4.2	6.0
104	DRR-DHAN-42	52	2	104	4.8	2.0	1.0
105	HIMALAYA-741	27	9.6	259	6.1	3.5	3.0
106	KAVYA	52	7.3	380	4.2	3.1	4.0
107	ZHY-1	52	12	624	8.5	3.5	5.0
108	MAS-26	94	21.6	2030	14.6	7.0	4.0
109	BM-71	54	6.5	351	4.5	2.0	4.0
110	BPT-5204	57	12.5	713	7.5	5.0	3.0
111	NBR-19	96	21.6	2074	15.1	6.5	4.0
112	NDR-369	91	18.3	1665	13.5	4.8	3.0
113	RDR-1158	91	14.4	1310	10.2	4.2	5.0
114	TME-80518	55	11.8	649	7.3	4.5	5.0
115	IET-23993	100	27	2700	19.8	7.2	6.0
116	R-18-19-447	74	13.4	992	9.1	4.3	4.0
117	RP-2421-1716	52	8.4	437	5.3	3.1	4.0
118	KNM-110	74	11.9	881	9.1	2.8	5.0
119	NDR-369	85	15.3	1301	10.3	5.0	4.0
120	RGP-155	85	12.3	1046	7.1	5.2	2.0
121	N-22	90	16.9	1521	12.5	4.4	3.0

Table 2. Estimates of range, variability, heritability and genetic advance for seed parameters of 121 germplasm lines

S. No.	Parameters	Mean	Range		Coefficient of Variation (%)		Heritability (h_2) _{bs} %	Mean of Gen. Adv % (at 5%)
			Min	Max	Phenotypic	Genotypic		
1.	Germination %	76.00	30.00	100.00	21.59	21.56	99.60	33.72
2.	Seedling Length (cm)	12.9	2.6	20.2	31.98	31.91	98.50	65.60
3.	Seedling vigor index	1024.1	78.0	1910.0	45.63	45.50	99.40	93.45
4.	Shoot length (cm)	8.1	1.2	12.5	31.00	30.97	96.20	63.75
5.	Root length (cm)	4.7	1.0	9.5	43.03	42.97	99.70	88.40
6.	Adventitious roots	4.00	1.00	8.00	33.23	33.16	95.60	68.18

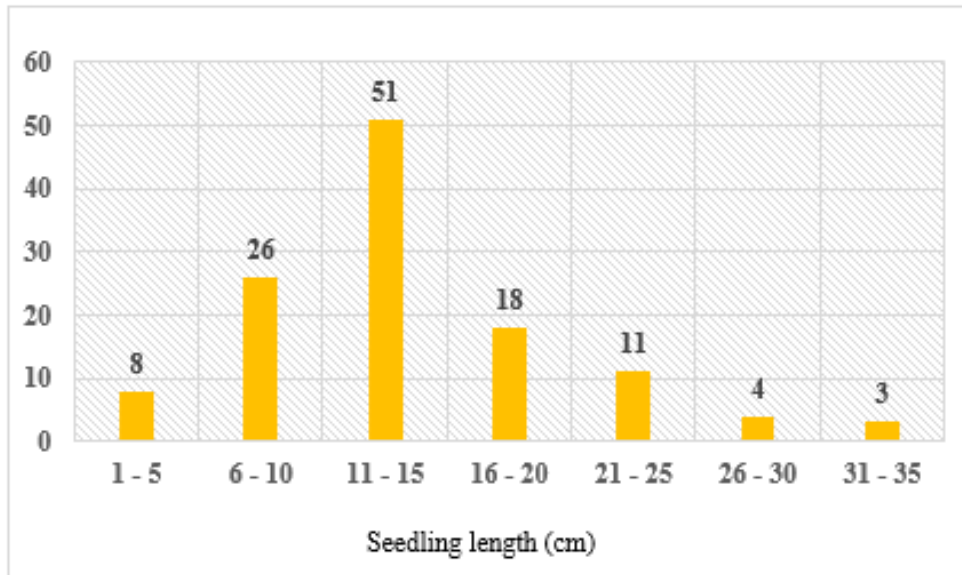


Fig. 2. Frequency distribution of rice germplasm lines for seedling length

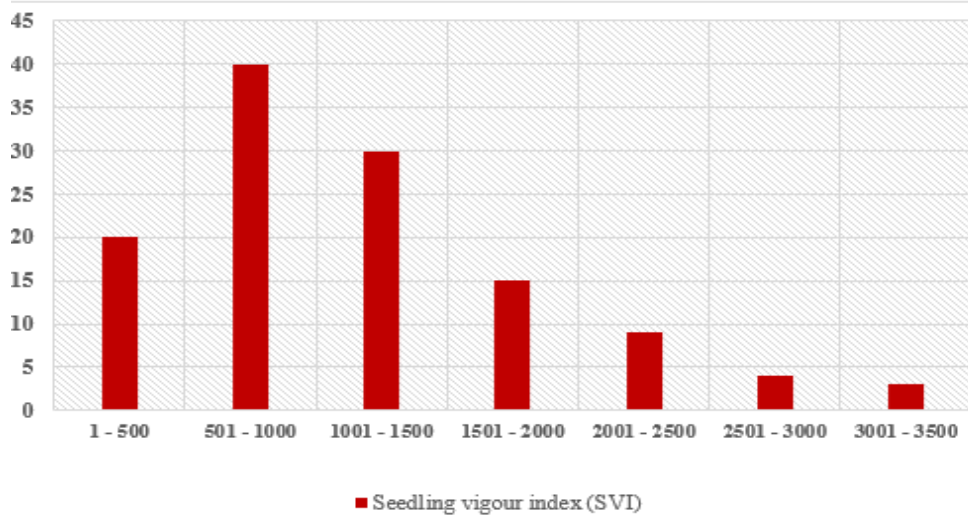


Fig. 3. Frequency distribution of rice germplasm lines for seedling vigour index

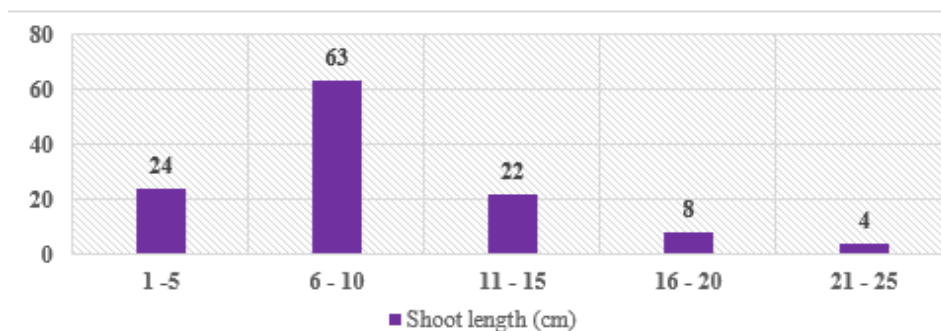


Fig. 4. Frequency distribution of rice germplasm lines for shoot length

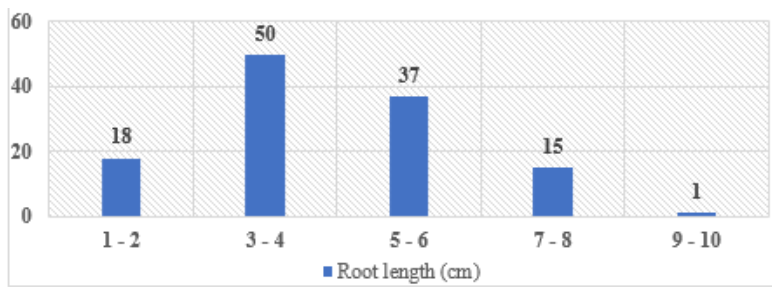


Fig. 5. Frequency distribution of rice germplasm lines for root length

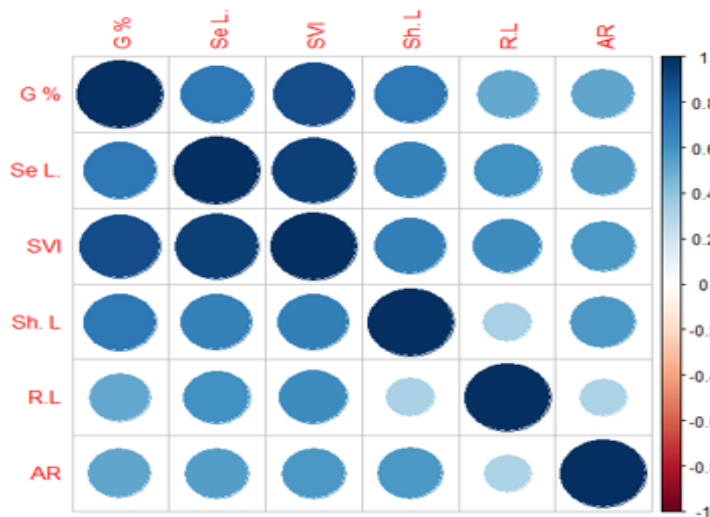


Fig. 6. Correlogram between different seed parameters under anaerobic condition

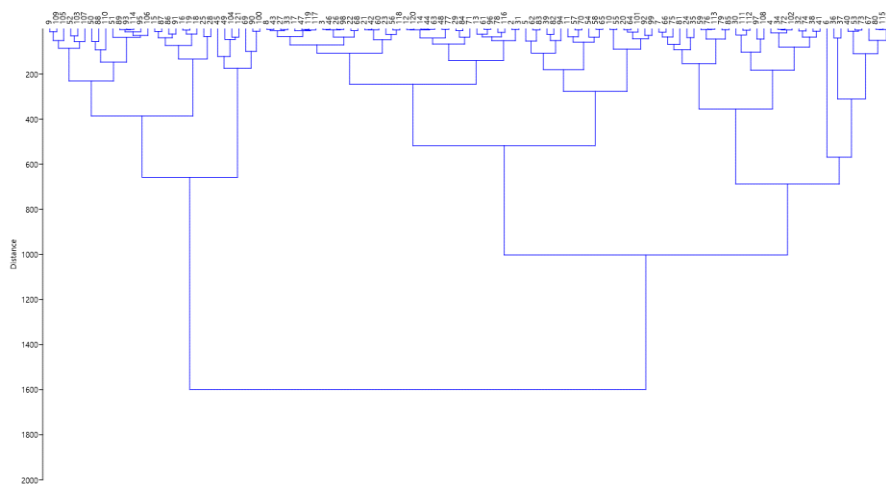


Fig. 7. Dendrogram depicting the 121 germplasm lines under anaerobic germination

3.6 Adventitious Roots

Adventitious roots facilitate gas transport, water and nutrient uptake during flooding. Following

flooding, they help take up nutrients and ensure plant survival [34]. The adventitious roots varied from 8.0cm in WGL 915 & RGP 60 to 1.0cm in Ravi, RGP 144, JGL 21098, DRR Dhan 42 & RGP 30 with a mean of 4.0cm.

3.7 Genetic Variability

The magnitude of genetic variability for different traits and the extent to which the desired trait is heritable plays a key role in the success of breeding programme. To understand the extent of variability, the phenotypic and genotypic coefficient of variation, broad-sense heritability and genetic advance are presented in Table 2. The results revealed that all the six seed parameters viz., germination % (21.59% & 21.56%), seedling length (31.98% & 31.91%), seedling vigour index (45.6% & 45.5%), shoot length (31.0% & 30.9%), root length (43.03% & 42.97%) and Adventitious roots (33.23% & 33.16%) exhibited high phenotypic and genotypic coefficient of variation respectively. The narrow range of difference between the PCV and GCV indicated that any selection pressure operated on these parameters may help to realize improvement at early generation.

Johnson et al. [29] suggested that heritability and genetic advance when calculated together would prove more useful in predicting the resultant effect of selection on phenotypic expression. The heritability and genetic advance were high for all six seed parameters viz., germination % (99.60% & 33.72%), seedling length (98.50% & 65.60%), seedling vigour index (99.40% & 93.45%), shoot length (96.20% & 63.75%), root length (99.70% & 88.40%) and Adventitious roots (95.60% & 68.18%) respectively. Highest heritability, genetic advance, PCV & GCV for seedling vigour index highlights the importance of trait for simple selection. seedling vigour is an indicator of potential seed germination, seedling growth and tolerance to adverse climatic factors [35].

3.8 Association Studies

The analysis of Pearson's correlation coefficients at both genotypic and phenotypic levels revealed that all the traits are positively correlated among themselves. Similar results were reported by Doley et al. [1]. The highest significant positive correlation was observed between the seedling length and seedling vigour index (0.93**) followed by germination % and seedling vigour index (0.88**) as shown in figure 6. Seedling vigour index calculated by multiplying both seedling length (root + shoot) and germination % is the most important parameter assessing the performance of anaerobic germination and growth in rice. [36] detailed the important traits associated with submergence tolerance during the initial growth stages for seedling establishment in direct-seeded rice. Germination

and early seedling growth are the two major parameters for rapid shoot elongation during anaerobic conditions [37]. According to El-Hendawy et al. [36] genotypes showing rapid elongation of coleoptile under anaerobic conditions can be characterized as tolerant to escape or avoid submergence during initial stages [38].

3.9 Cluster Analysis

Hierarchical cluster analysis of some seed parameters is depicted in Figure 7. The 121 genotypes were grouped into four clusters i.e., cluster 1 with 19 genotypes, cluster 2 with highest 73 genotypes, cluster 3 with 22 genotypes and cluster 4 with least genotypes (7). Cluster 1 is divided into sub-clusters 1a with 10 genotypes and 1b with 9 genotypes, Cluster 2 into sub-clusters 2a with 46 genotypes and 2b with 27 genotypes, Cluster 3 into sub-clusters 3a with 12 genotypes and 3b with 10 genotypes and Cluster 4 into sub-clusters 4a with 4 genotypes and 4b with 3 genotypes. Cluster 3 & 4 has genotypes with above standard germination % (80%), highest seedling length (33.1cm to 20.3cm) and high vigour index (3310 to 2030) [39,40].

4. CONCLUSION

In the current appraisal, totally 10 AG tolerant lines viz., RDR 7555, WGL 915, CSR 27, RGP 103, RGP 57, RGP 58, IRTON 103, IET 23993, RGP 60 & MTU NS1 have been identified with highest germination %, high seedling vigour index and longest shoot length to thrive anoxic/hypoxic conditions. These lines can be utilized in the hybridization programme to evolve an elite cultivar with tolerance to anaerobic conditions. High GCV, PCV, heritability coupled with high GAM for the traits viz., germination %, seedling length, seedling vigour index, shoot length, root length and Adventitious roots. High significant positive correlation was observed between the seedling length and seedling vigour index followed by germination % and seedling vigour index. Cluster 3 & 4 has 29 genotypes with above standard germination %, highest seedling length and high vigour index. This genetic information will help to design appropriate breeding strategy for development of rice cultivars to suit aerobic or DSR conditions.

ACKNOWLEDGEMENT

The authors are thankful to PJTSAU for the financial support and encouragement to take up

the research at RS & RRS, Rudrur, Nizamabad, Telangana, India.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- Doley D, Barua M, Sarma D, Barua PK. Screening and enhancement of anaerobic germination of rice genotypes by pre-sowing seed treatments. *Current Science*. 2018;115:1185-1190.
- Khush GS. What it will take to feed 5.0 billion rice consumers in 2030. *Plant Molecular Biology*. 2005;59:1-6, Available:<https://doi.org/10.1007/s11103-005-2159-5>.
- Ismail AM, Ella ES, Vergara GV, Mackill DJ. Mechanisms associated with tolerance for flooding during germination and early seedling growth in rice (*Oryza sativa*). *Ann. Bot.* 2009;103:197–209.
- Ray S, Vijayan J, Sarkar RK. Germination stage oxygen deficiency (GSOD): An emerging stress in the era of changing trends in climate and rice cultivation practice. *Front. Plant Sci*. 2016;7.
- Vibha D. Water and Agriculture in India. Background paper for the South Asia expert panel during the Global Forum for Food and Agriculture (GFFA). Federal ministry of food and agriculture; 2017.
- Anonymous World Bank Group – water; 2020. Available:<https://www.worldbank/water.2020>.
- Sanchez PA. Puddling tropical soils - Effects on water losses. *Soil Sci*. 1973;115: 303-308.
- Aggarwal GC, Sidhu AS, Sekhon NK, Sandhu KS, Sur HS. Puddling Management effects on crop response in a rice-wheat cropping system. *Soil Till. Res*. 1995;36:129–139.
- Sharma PK, De Datta SK. Effect of puddling on soil physical properties and processes. In *Soil Physics and Rice*. 1985;217–234.
- Sharma PK, Ladha JK, Bhushan L. Soil physical effects of puddling in rice-wheat Cropping systems. In “Improving the Productivity and Sustainability of Rice-Wheat Systems: Issues and impacts. *Plant Molecular Biology*. 2003;59(1):1-6.
- Singh UM, Yadav S, Dixit S, Ramayya PJ, Devi MN, Raman KA, Kumar A. QTL hotspots for early vigor and related traits under dry direct-seeded system in rice (*Oryza sativa* L.). *Frontiers in Plant Science*. 2017;8:1-14.
- Atwell B, Waters I, Greenway H. The effect of oxygen and turbulence on elongation of coleoptiles of submergence-tolerant and-intolerant rice cultivars. *J. Exp. Bot*. 1982;33:1030–1044.
- Perata P, Guglielminetti L, Alpi A. Mobilization of endosperm reserves in cereal seeds under anoxia. *Ann. Bot* 1997;79:49–56.
- Alpi A, Beevers H. Effects of O₂ concentration on rice seedlings. *Plant Physiology*. 1983;71:30–34.
- Guglielminetti L, Yamaguchi J, Perata P, Alpi A. Amylolytic activities in cereal seeds under aerobic and anaerobic conditions. *Plant Physiology*. 1995;109: 1069–1076.
- Miro B, Ismail AM. Tolerance of anaerobic conditions caused by flooding during germination and early growth in rice (*Oryza sativa* L.). *Front. Plant Sci*. 2013;4:269. DOI: 10.3389/fpls.2013.00269
- Yamauchi M, Aguilar AM, Vaughan DA, Seshu DV. Rice (*Oryza sativa* L.) germplasm suitable for direct sowing under flooded soil surface. *Euphytica*. 1993; 67:177–184.
- Yamauchi M, Herradura PS, Aguilar AM. Genotype difference in rice post-germination growth under hypoxia. *Plant Sci*. 1994;100:105–113.
- Yamauchi M, Chuong PV. Rice seedling establishment as affected by cultivar, seed coating with calcium peroxide, sowing depth, and water level. *Field Crops Res*. 1995;41:123–134.
- Biswas JK and Yamauchi M. Mechanism of seedling establishment of direct seeded rice (*Oryza sativa* L.) under lowland conditions. *Bot Bull Acad Sin*. 1997;38:29–32.
- Ella ES, Dionisio-Sese ML, Ismail AM. Proper management improves seedling survival and growth during early flooding in contrasting rice (*Oryza sativa* L.) genotypes. *Crop Sci*. 2010;50:1997–2008.
- Septiningsih EM, Ignacio JCI, Sendon PMD, Sanchez DL, Ismail AM, Mackill DJ. QTL mapping and confirmation for tolerance of anaerobic conditions during germination derived from the rice landrace

- Ma-Zhan Red. Theor. Appl. Genet. 2013;126:1357–1366.
23. Bailey-Serres J and Chang R. Sensing and signalling in response to oxygen deprivation in plants and other organisms. *Ann Bot.* 2005;96:507–518. DOI: 10.1093/aob/mci206
24. Ismail AM, Johnson D, Ella E, Vergara GV, Baltazar AM. Adaptation to flooding during emergence and seedling growth in rice and weeds, and implications for crop establishment. *AoB Plants*; 2012. DOI: 10.1093/aobpla/pls019
25. ISTA International rules for seed testing. *Seed Sci. Technol.* 1985;13:356–513.
26. Angaji SA, Septiningsih EM, Mackill DJ, Ismail AM. Identification of QTLs associated with tolerance of anaerobic conditions during germination in rice (*Oryza sativa* L.). *Euphytica* 2010;172: 159–168.
27. Abdul-Baki AA, Anderson JD. Vigor determination in soybean seed by multiple criteria. *Crop Sci.* 1973;13:630-633.
28. Falconer DS. Introduction to quantitative genetics. Longmans Green, London/New York, 1981;33-34.
29. Johnson HW, Robinson HF, Comstock RE Estimation of genetic and environmental variability in soybeans. *Agronomy Journal.* 1955;47:314-318.
30. Manigbas NL, Renando OS, Wilhelmina VB, Angelo JN, Emily CA, Thelma FP, Rolando TC. Development of screening methods for anaerobic germination and seedling vigor in direct wet seeded rice culture. *Philippine Journal of Crop Science.* 2008;33(3):34-44.
31. Huang SB, Greenway H, Colmer TD. Anoxia tolerance in rice seedlings: Exogenous glucose improves growth of an anoxia-intolerant, but not of a 'tolerant' genotype. *J. Exp. Bot.* 2003;54:2363–2373.
32. Ling J, Ming-yu H, Chun-ming W, Jian-min W. Quantitative trait loci and epistatic analysis of seed anoxia germinability in rice (*Oryza sativa*). *Rice Science.* 2004;11(5-6):238-244.
33. Kawai M, Uchimiya H. Coleoptile senescence in rice (*Oryza sativa* L.). *Ann. Bot.* 2000;58:405–414.
34. Sauter M. Root responses to flooding. *Current Opinion in Plant Biology.* 2013;16 (3):282-286.
35. Mahender A, Anandan A, Pradhan SK. Early seedling vigour, an imperative trait for direct seeded rice: An overview on physio-morphological parameters and molecular markers. *Planta.* 2015;241: 1027–1050.
36. El-Hendawy S, Al-Suhaibani N, Schmidhalter U, Sakagami JI. Adaptive traits associated with tolerance to flash flooding during emergence and early seedling growth stages in rice. *Plant Omics Journal.* 2014;7:474-489.
37. Cui KH, Peng SB, Xing YZ, Xu CG, Yu SB, Zhang Q. Molecular dissection of seedling-vigor and associated physiological traits in rice. *Theoretical and Applied Genetics.* 2002;105:745–753.
38. Perata P, Guglielminetti L, Alpi A. Anaerobic carbohydrate metabolism in wheat and barley, two anoxia-intolerant cereal seeds. *J. Exp. Bot.* 1996;47:999–1006.
39. Perata P, Geshi N, Yamaguchi J, Akazawa T. Effect of anoxia on the induction of alpha-amylase in cereal seeds. *Planta* 1993;191:402–408.
40. Umarani E, Hemalatha V, Bhadana VP, Senguttuvel P, Subbarao LV, Neeraja CN, Ravi PY, Suneetha K. Screening of Rice (*Oryza sativa* L.) Genotypes for anaerobic germination. *Int. J. Pure App. Biosci.* 2018;6 (5):1318-1325.

© Copyright (2024): Author(s). The licensee is the journal publisher. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here:
<https://www.sdiarticle5.com/review-history/112497>