Original Research Article

Genetic Assessment of Anaerobic Germination in Rice

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), 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 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).

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. Rice provides 30–75% of the total calories to more than 3 billion Asians (Khush, 2005). Agriculture in India is dependent on the monsoon. 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 (Ismail et al. 2009; Ray et al. 2016).

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 (Vibha, 2017). 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 (World Bank Group- Water, 2020). 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 (Sanchez, 1973). But repeated puddling adversely affects soil physical properties by destroying soil aggregates, reducing permeability in subsurface layers, and forming hard-pans at shallow depths (Aggarwal et al., 1995; Sharma and De Datta, 1985; Sharma et al., 2003). 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 (Singh et al., 2017). Rice seeds can germinate without oxygen (Atwell et al. 1982, Perata et al. 1997), unlike other major cereals such as wheat (Alpi and Beevers 1983, Perata et al., 1997), oat (Alpi and Beevers 1983), and barley (Perata et al., 1997), because it can make its enzyme for starch degradation without oxygen (Guglielminetti et al., 1995). 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 (Miro and Ismail, 2013). 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 (Yamauchi et al., 1993; Yamauchi et al., 1994; Yamauchi and Chuong, 1995; Biswas and Yamauchi, 1997; Ella et al., 2010; Septiningsih et al., 2013), seedling growth and adjustment of carbohydrate metabolism (Bailey-Serres and Chang, 2005; Ismail et al., 2009; Ismail et al., 2012), fast coleoptile elongation, fast leaf and root development (Hsu and Tung, 2015; Kretzschmar 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. 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 (Doley et al., 2018).

2. Materials and Methods:

2.1 Plant Material: The seed material consisted of 266 germplasm lines collected all over India. The seeds were obtained from the Plant Breeding section, PJTSAU, 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 (1985) procedure.

2.2 Protray Method: In the shade, a net flooded soil evaluation system was established concerning the IRRI method (Angaji et al. 2010, Septiningsih et al. 2013). 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 2cm 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.

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% respectively) and heritability was estimated according to the method of Falconer (1981) and the genetic advance was computed following the formula suggested by Johnson et al. (1955).

3. Results & 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 Ismail et al. (2009). 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.

The establishment of rice under anaerobic conditions goes with a sequence of biochemical changes in enzymes such as α - amylase activity, peroxidase, and alcohol dehydrogenase. It has been reported that among the enzymes α – amylase plays an effective role in enhancing the germination ability of seed by degrading starch into sugars Perata et al. (1993). The accumulation of these enzymes was reported in AG tolerant lines and absence in intolerant lines. In intolerant lines, the starch is not hydrolyzed inro sugars which ultimately leads to sugar starvation and failure in germination Perata et al. (1996). This greater amylase activity was also associated with several essential criteria viz., maintenance of higher soluble sugar concentrations in germinating seeds, greater starch depletion, better seedling growth, and higher seedling survival Umarani et al. (2017).

In the present study, 121 germplasms showed germination under anaerobic conditions and they were found varying among themselves for AG %, seed vigour index (SVI), seedling length, shoot length, root length, and number of adventitious roots (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 figure 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. 2008) 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 figure 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 figure 3. Seedling vigor index was calculated by using the below formula as suggested by (Abdul-Baki and Anderson, 1973) expressed in the whole number.

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

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 (Huang et al. 2003), hence shoot length of seedlings including the coleoptiles is used as a marker to determine anaerobic germination tolerance Ling et al. (2004). 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 figure 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 (Alpi and Beevers, 1983; Kawai and Uchimiya, 2000). 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).

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 (Sauter, 2013). 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. Study from table 2 revealed that all the six seed parameters *viz.*, germination % (21.5% & 21.5%), seedling length (31.9% & 31.9%), 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. 1955 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 (Mahender et al. 2015).

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 at both levels. Similar results were reported by Doley et al. 2018. 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. (El-Hendawy et al. 2014) 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 (Cui et al. 2002). According to El-Hendawy et al. 2014 genotypes showing rapid elongation of coleoptile under anaerobic conditions can be characterized as tolerant to escape or avoid submergence during initial stages.

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).

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 *vi*, 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.

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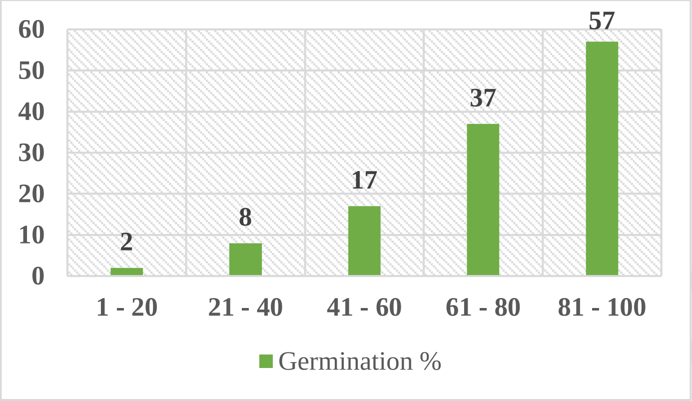

Figure 1: Frequency distribution of rice germplasm lines for germination %

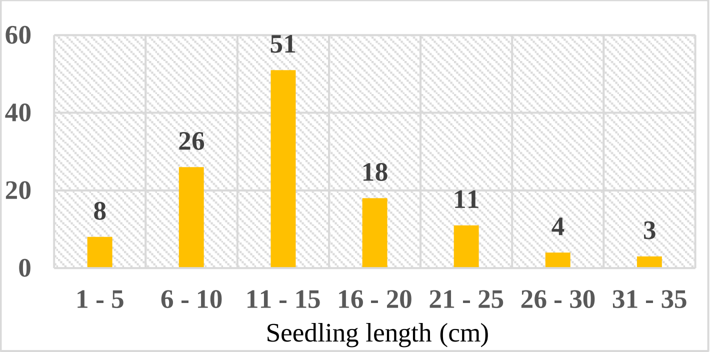

Figure 2: Frequency distribution of rice germplasm lines for seedling length

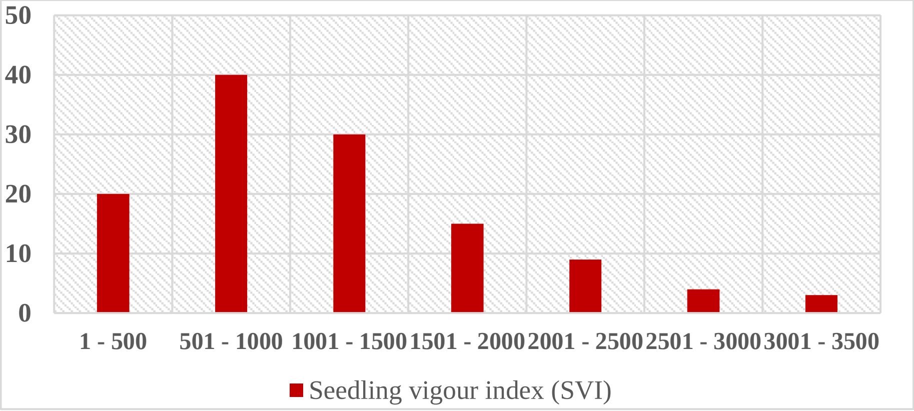

Figure 3: Frequency distribution of rice germplasm lines for seedling vigour index

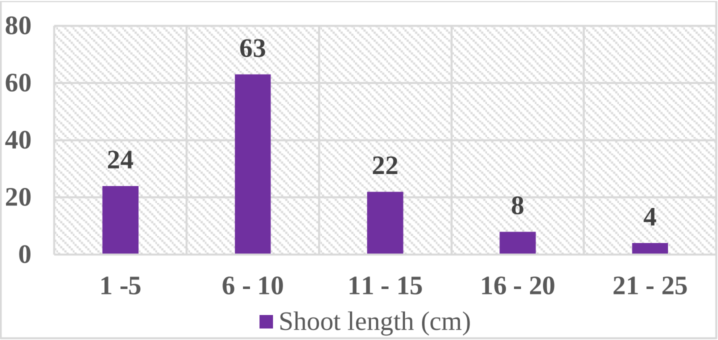

Figure 4: Frequency distribution of rice germplasm lines for shoot length

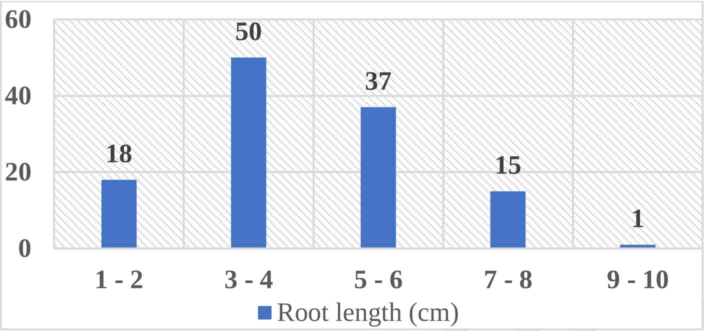

Figure 5: Frequency distribution of rice germplasm lines for root lengthvv

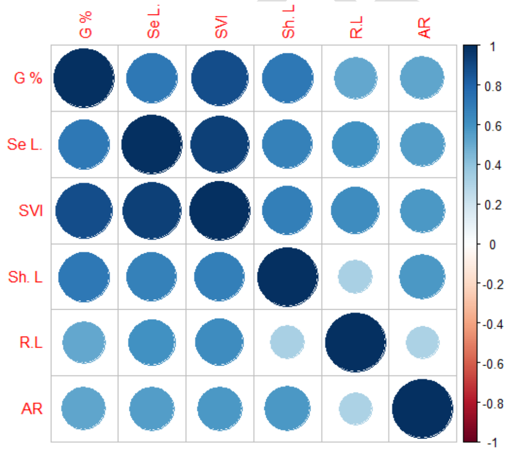

Figure 6. Correlogram between different seed parameters under anaerobic condition

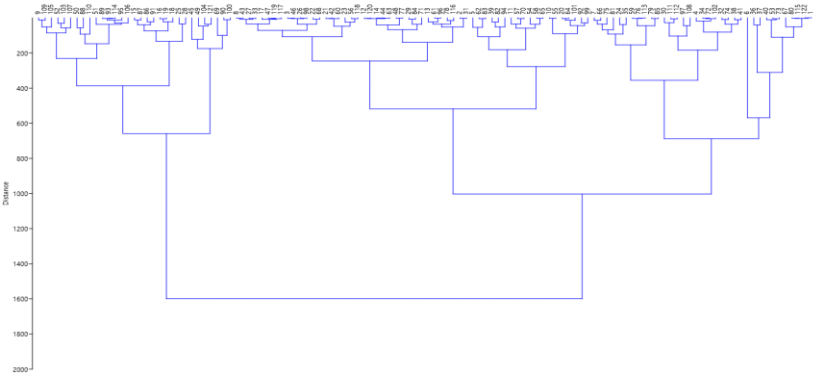

Figure 7. Dendrogram depicting the 121 germplasm lines under anaerobic germination

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
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
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
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

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

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