Bioscene

Bioscene
Volume- 22 Number- 02
ISSN: 1539-2422 (P) 2055-1583 (O)
www.explorebioscene.com

Assessment of Aerobic and Anaerobic Germination of Different Deep Water Rice Landraces

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Abstract: Rice is the staple food crop for more than half of the world's population. Majority of the population of India is highly dependent on the production of rice. Most of the rice producing states of India suffer heavy rainfall during the monsoon season especially the North-Eastern states such as Assam. Generally, the traditional rice varieties cannot withstand the adverse effects caused by prolonged submerged conditions caused by flood. But most of the deep water rice varieties show even better growth in submerged conditions. DWR is also bestowed with a multitude of nutrients, minerals and anti-oxidants which make it a desirable food crop. However during sowing period, a protracted water logged condition may kill the seedlings. Therefore, this study aims to analyze the germination percentage of different DWR varieties in aerobic condition and anaerobic conditions and to compare the growth of the seedlings in both the conditions. The study revealed that Kola bao, Sonjul, Ikora, Rangadhar kekowa, Adoliya, Borehha, Amona and Biria bhonga bao showed 100% germination in aerobic condition. However, in case of anaerobic condition, Maguri showed the highest germination percentage. DWR is only rice variety that can be grown in the areas inundated by flood and serve as a subsistence crop for the locals.

Keywords: Aerobic; Anaerobic; Deep water rice; Germination percentage; Root length; Shoot length

Introduction

Rice, *Oryza sativa* L., is one of the most important cereal crop cultivated as staple crop in many nations around the globe. It serves as the staple food for more than 60% of the world's population especially for the people of South-East Asia (Singh et al., 2018). South Asian countries including India are highly dependent on rice cultivation which affects their economies in a significant way. Rice apart from being a source of energy is a store house of various macro and micro nutrients including a number of vitamins and minerals. It is a very good source of complex carbohydrates, possess a reasonable amount of protein 6-10%, carbohydrate 70-80%, minerals 1.2-2% and vitamins such as thiamine (B1), riboflavin (B_2), niacin (B3) and Tocopherol (vit E). In India, rice contributes about 43% of total food grain production and 46% of the total cereal production (Singh et al., 2018). Rice is considered as a semi-aquatic plant as it is cultivated in various hydrologies

ranging from aerobic conditions in uplands to submerged flooded anaerobic conditions in lowlands. Majority of the modern rice varieties are vulnerable to submerged flooded anaerobic condition in lowlands that experience high rainfall during germination and early growth stages, however there are few landraces of rice which are highly capable of germination even under flooded conditions (Miro and Ismail, 2013).

Majority of deep water rice varieties are known for their high tolerance to submerged condition caused by floods. Therefore, they serve as a subsistence crop for the farm dependent families during seasons with heavy rainfall and are the only rice varieties that can be cultivated in water logged conditions during monsoon season (Rajkhowa and Borgohain, 2024). Studies have shown that DWR varieties adopt various mechanisms to tackle and survive different flood situations during monsoon season. Genes such as *Submergence 1* (*Sub1*), Expansins, SNORKELs and major QTLs confer submergence to DWR varieties (Lee and Kende, 2001; Hattori et al., 2009; Hattori et al., 2011). Under flooding situations, deep water rice can grow and attain a height upto 2m (Rohilla et al., 2019). In India, DWR is cultivated in many states such as Assam, Bihar, Orissa, Uttar Pradesh and West Bengal. It has been estimated that around 100,000 ha of land is under deep water rice cultivation in Assam (Rohilla et al., 2019). In Assam, deep water rice is known as Bao dhan among the locals(Rajkhowa and Borgohain, 2025). Both white and red rice varieties are cultivated in Assam. The kernels of Bao dhan or deep water rice varieties are generally red in colour due to presence of pigments such as anthocyanin. Deep water rice apart from being submergence tolerant are nutritionally rich than many other advanced varieties. Deep water rice or Bao dhan is considered as an organic crop because the farmers cultivating them have poor economic conditions and therefore do not have scope to apply chemical fertilizers on the crop during water stagnation period (Rohilla et al., 2019). Even though they are bestowed with all these characteristics, deep water rice is understudied and needed to be explored more. Deep water rice varieties add up to nearly 10% of the total rice production. Although their yields are low, DWR back 100 million people living in areas that are affected by extensive flood annually during the rainy season, generally in the river deltas in South and Southeast Asia (Sauter, 2000).

Anoxia or hypoxia are stress conditions that prevail in plants during development of different organs of plants such as seeds because of submerged condition caused by flooding (Kumari et al., 2022). In most cases, in such anaerobic conditions it becomes difficult for the plants to develop its parts normally and therefore its growth is hampered or may even die. In contrast, deep water rice can withstand submersion due to flood upto an extent (Kumari et al., 2022). However, traditional rice varieties cannot survive in a prolonged flooded condition. It was found that seeds germinating under anoxic condition showed an increased availability of Alpha expansion genes EXPA2 and EXPA4 mRNA levels (Huang et al., 2000).

DWR is tolerant to submerged conditions during flooded situation, however prolonged submersion especially during seed sowing period can cause death of the seedlings. During submersion, it was found that the maximum gradual increase in height of the plant is seen during the early vegetative stage *i.e.,* 4-6 weeks after germination but in late vegetative stage or in advanced growth stage, the ability to elongate gradually decrease (Rohilla et al., 2019). Applying the GWAS (Genome-Wide Association Studies) approach, 20 important genes were identified that are found to be correlated with AG-linked traits. Out of them, two most admissible genes *viz.,* OsXDH1 and SSXT were located in Chromosome 3 and Chromosome 12. Both of these genes were identified to be linked with anaerobic response index *i.e.,* increase in the coleoptile length under water in anaerobic condition with respect to control (Rohilla et al., 2020). The germination as well as elongation of the plant during such an anaerobic condition however depends on the variety of the deep water rice. Different varieties behave differently to water stress conditions. Therefore, this study was conducted on different deep water rice varieties to analyze their ability to germinate in aerobic as well as in anaerobic conditions and to identify varieties that showed high germination percentage in anaerobic condition. It also focuses on the growth of the seedlings in both aerobic and anaerobic conditions.

Materials and Methods

For the present study, twenty one deep water rice varieties were collected from local farmers of Lakhimpur District of Assam, India. The experiments were conducted in Department of Botany of North Lakhimpur College for both aerobic and anaerobic germination in plastic pots of 15cm height each. For each rice sample, 12 replicas were taken in each pot. Field soil was taken for the experiment. At first, the rice seeds were surface sterilized with 0.1% mercuric chloride ($HgCl_2$). For aerobic germination, holed pots were used that were filled with field soil up to 9cm in height and for anaerobic germination, intact pots were used with no holes and each pot was filled with same field soil up to 9cm. The sterilized seeds were sown into the soil. In case of aerobic experiment, the pots were watered each day to keep the soil moist enough whereas for anaerobic experiment, the water level (5 cm) in the pots was maintained regularly to provide an anaerobic condition. After 7 days of sowing, the germination percentage was recorded along with root length and shoot length of the seedlings using a centimeter scale. For the analysis of root and shoot length, out of 12 replicas that were used in germination experiments, 3 replicas were used. For calculation of seed germination percentage (GP), the following formula was used (Vibhuti et al., 2015)

GP = Number of total germinated seeds/ Total number of seeds tested × 100

Results and Discussion

After conducting the study, it was found that Kola bao, Sonjul, Ikora, Rangadhar kekowa, Adoliya, Borehha, Amona and Biria bhonga bao showed 100% germination in aerobic condition. However, in case of anaerobic condition, Maguri showed the highest germination, *i.e.,* out of 12 replicas, 10 seeds (83.3%) germinated successfully, and Rangadhar kekowa and Biria bhonga bao both showed germination percentage 66.6%. In case of aerobic germination, all the DWR varieties germinated although the germination percentage varied among the varieties but in case of anaerobic condition, out of 21 DWR varieties, 20 varieties showed germination. However, none of the Jalpriya bao seeds showed germination. The difference between the germination percentage in aerobic and anaerobic condition was seen to be very prominent except for Maguri Bao which showed the same germination percentage in both aerobic as well as anaerobic condition. Also the root length as well as shoot length of the seedlings grown in aerobic and anaerobic condition showed a significant difference. The seedlings grown in aerobic condition showed better growth than seedlings grown in anaerobic condition. In case of anaerobic condition, seedlings of all the varieties showed shorter shoots. However, in case of average root length, some of the DWR varieties showed more growth in anaerobic conditions than in aerobic conditions. Maguri, Ramdulari and Biriabhongashowed longer roots in anaerobic condition.

Table 1: Germination percentage of different DWR landraces in aerobic and anaerobic condition

Sl. No.	Rice varieties	Germinated seeds in aerobic condition (total 12 replicas)	Germination percentage (aerobic condition)	Germinated seeds in anaerobic condition (total 12 replicas)	Germination percentage (anaerobic condition)
1	Kola bao	12	100	05	41.6
2	Jalpriya	05	41.6	00	00.0
3	Sonjul	12	100	02	16.6
4	Maguri	10	83.3	10	83.3
5	Palia	03	25.0	04	33.3
6	Ikora	12	100	02	16.6
7	Tulsi	05	41.6	03	25.0
8	Dubori	09	75.0	02	16.6
9	Ramdulari	08	66.6	06	50.0
10	Rangadhar kekowa	12	100	08	66.6
11	Adoliya	12	100	04	33.3

12	Panchanan	11	91.6	04	33.3
13	Mirem	07	58.3	06	50.0
14	Borehha	12	100	06	50.0
15	Boola	11	91.6	04	33.3
16	Negheri	07	58.3	02	16.6
17	Amona	12	100	07	58.3
18	Panikekowa	08	66.6	05	41.6
19	Biroi	09	75	05	41.6
20	Biria bhonga	12	100	08	66.6
21	Zeng bao	07	58.3	04	33.3

Table 2: Shoot and root length of DWR seedlings in aerobic and anaerobic condition

Sl no	Rice varieties	Aerobic germination								Anaerobic germination							
		Shoot length			Avg	Root length			Avg	Shoot length			Avg	Root length			Avg
		R1	R2	R3		R1	R2	R3		R1	R2	R3		R1	R2	R3	
1	Kola Bao	15.0	14.5	14.0	14.5	4.2	4.2	4.0	4.1	3.1	2.9	2.8	2.9	0.2	0.1	0.0	0.1
2	Jalpriya	11.9	8.5	6.5	8.9	4.3	3.0	3.5	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	Sonjul	17.1	16.0	15.5	16.2	5.0	4.0	3.5	4.2	9.1	1.7	0.0	3.6	7.1	0.0	0.0	2.3
4	Maguri	17.6	21.7	17.8	19.0	4.5	4.5	3.5	4.2	16.3	9.3	7.2	10.9	9.6	4.8	5.8	6.7
5	Palia	18.0	12.6	11.5	14.0	4.7	4.5	3.5	4.6	10.3	5.9	5.5	7.2	4.4	2.2	1.7	2.8
6	Ikora	16.7	16.3	16.2	16.4	4.0	4.5	4.7	4.4	10.4	1.6	0.0	4.0	4.6	0.2	0.0	1.6
7	Tulsi	15.6	14.0	8.5	12.7	5.0	4.5	4.7	4.7	4.9	3.9	1.6	3.5	2.4	0.2	0.1	0.9
8	Dubori	16.8	16.5	16.5	16.6	5.5	5.2	4.0	4.9	2.3	0.9	0.0	1.6	1.7	0.0	0.0	0.6
9	Ramdulari	16.8	13.5	13.2	14.5	5.1	4.0	3.0	4.0	15.4	9.3	2.7	9.1	7.8	7.3	1.3	5.5
10	Rangadharkekowa	17.7	17.5	15.5	16.9	3.8	4.0	3.8	3.9	12.9	6.8	1.9	7.2	6.0	3.1	0.6	3.2
11	Adoliya	15.6	12.0	11.3	12.9	4.8	3.8	3.5	4.0	5.6	3.2	3.0	3.9	3.6	2.0	0.9	2.2
12	Panchanan	17.0	16.5	14.5	16	3.8	4.0	2.5	3.4	11.0	7.9	5.3	8.1	6.3	2.9	2.3	3.8
13	Mirem	19.8	19.5	13.1	17.5	5.8	8.0	4.0	5.9	10.7	5.9	1.7	6.1	5.4	3.9	0.0	3.1
14	Borehha	19.3	17.3	17.2	17.9	10.0	4.5	8.0	7.5	4.2	4.9	3.7	4.3	1.6	0.0	0.5	0.7
15	Boola	14.5	10.2	9.6	11.4	4.3	4.0	4.0	4.1	7.3	4.3	4.1	5.2	3.1	0.3	0.3	1.2
16	Negheri	8.5	8.2	8.0	8.2	3.5	3.2	3.5	3.4	3.3	3.6	3.0	3.3	0.2	0.6	0.3	0.4
17	Amona	13.0	11.3	10.8	11.7	3.0	3.5	3.3	3.3	8.8	4.7	3.6	5.7	2.7	1.4	0.3	1.5
18	Panikekowa	14.7	14.6	13.1	14.1	6.5	7.0	4.0	5.8	1.3	3.9	2.4	2.5	0.0	2.1	1.5	1.2
19	Biroi	16.4	14.2	13.2	14.6	5.0	4.0	4.5	4.5	4.7	3.3	2.5	3.5	3.6	3.1	0.0	2.2
20	Biria bhonga	15.5	14.0	13.0	14.2	4.5	4.0	5.0	4.5	13.1	8.3	8.2	9.8	8.3	3.7	3.1	5.0
21	Zeng bao	18.8	15.7	9.5	14.7	8.0	7.5	4.5	6.7	8.6	4.8	2.8	5.4	2.8	1.5	0.1	1.5

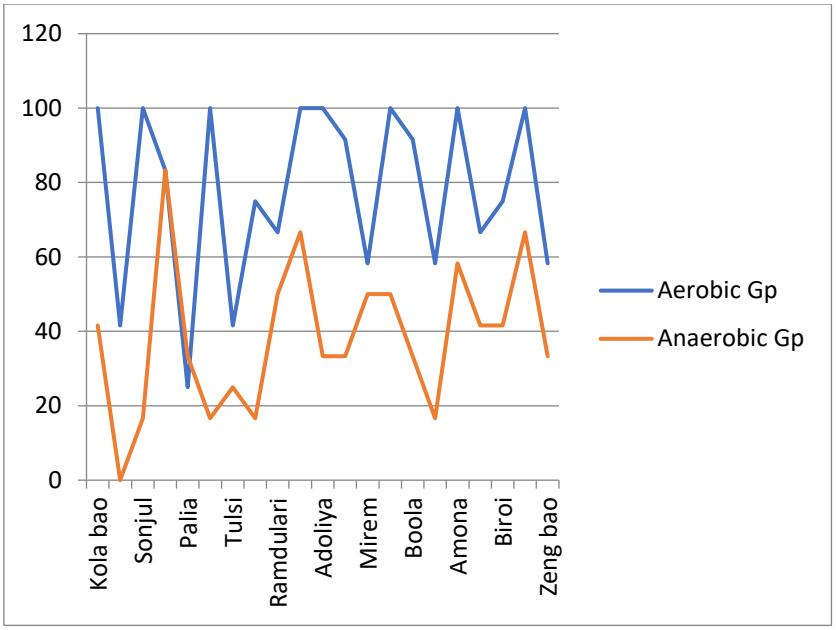

Figure 1: Germination percentage of DWR seeds in aerobic and anaerobic condition

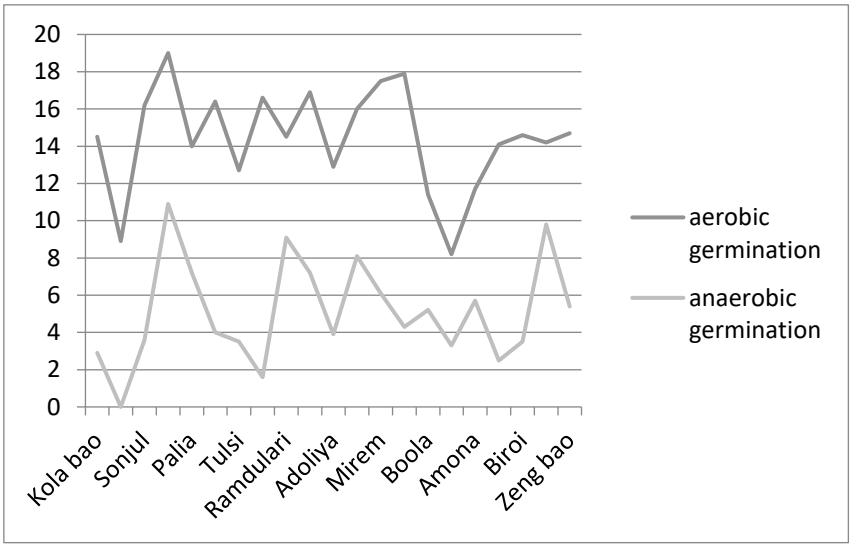

Figure 2: Shoot length of DWR seedlings grown in aerobic and anaerobic condition

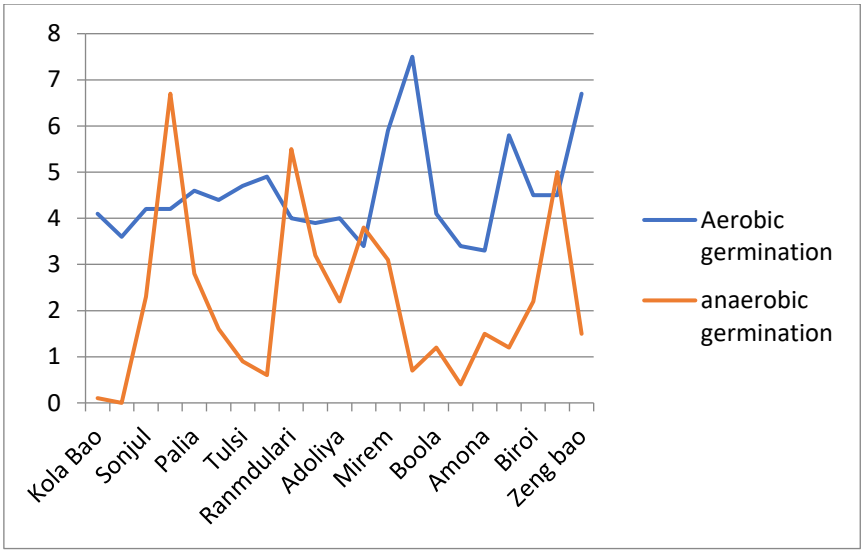

Figure 3: Root length of DWR seedlings grown in aerobic and anaerobic condition

Conclusion

Rice is a crop that can be cultivated in uplands as well in lowlands. Therefore, a huge diversity can be seen in the varieties. Deep water rice serves as a boon to the people living in lowlands that are hugely affected by flood during monsoon season where other rice varieties fail to withstand water-logged conditions. Thus, deep water rice plays a crucial role in the lives of farm dependent people living in the flood affected areas. After conducting the studies, the results demonstrated that majority of the deep water rice germinate even in water stress conditions although the germination percentages were lower than that in aerobic condition. Few varieties showed even better growth in submerged conditions and can be said that they are tolerant to such situations. Identification of more and better deep water rice varieties tolerant to anaerobic germination is important so that they can be further used in field trials and then introduce the desirable seeds to farmers.

Declaration: The authors declare that they do not have any conflict of interest.

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