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Effect of anaerobic condition on germination and seedling growth in different rice cultivars

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Abstract
Present investigation was conducted to find out "Effect of anaerobic condition on germination and seedling growth in different rice cultivars". The experiment was laid out in complete randomized design in artificially constructed submergence ponds/field (Control condition) with twenty rice varieties *i.e.* NDR-9503, NDR-8555, NDR-8820, NDR-8610, NDR-8588, NDR-9516, NDR-8602, NDR-9453, NDR-9460, NDR-9521, NDR-8532, NDR-8016, NDR-9479, NDR-9930112, NDR-8846-2, NDR-8522-2, NDR-9467, IR-64, NDR-9930111, NDR-9730018 at the experimental site of the department of crop physiology, Narendra Deva University of Agriculture and technology, Kumarganj, Faizabad (UP) during wet season 2014. Experiment comprised of 1) Normal condition 2) Anaerobic condition set. Under normal condition seeds are allowed to germinate in petri dish and various morphological traits were measured periodically. The salient findings of the present investigation are given below. Tolerant rice genotypes like NDR-9930111, NDR-9930112, NDR-8610, NDR-8522-2, NDR-9453, NDR 9479, NDR 8532, NDR-9521, NDR-9460, NDR-9516 had higher germination and seedling growth as compared to intolerant genotype such as NDR-9503, NDR-8555, NDR-8820, NDR-8588, NDR-8602, NDR-8016, NDR-9467, IR-64 under anaerobic condition.

Keywords: Rice, Anaerobic, Germination, Seedling growth

Introduction
Rice (*Oryza sativa* L., 2n= 24), belongs to the family Poaceae (Graminae). Rice is the most important food crop of the developing world and is the staple food of more than half of the world's population. It is especially important crop of Asia, where more than 90% of world rice is grown and consumed and where more than half of world's people live. Rice farming is about 10,000 year old and largest single use of land for producing food. Rice fields covers 11% of Earth's entire aerable land. Two rice species are important cereals for human nutrition *i.e. Oryza sativa* grown worldwide and *Oryza glaberrima* grown in parts of West Africa. Rice is rich in nutrients and contains a number of vitamins and minerals. It is an excellent source of complex carbohydrates- the best source of energy. It contains a reasonable amount of protein 6-10%, carbohydrate 70-80%, mineral 1.2-2% and vitamins (Riboflavin, Thiamine, Niacin and vitamin E). Rice contributes 43% of total food grain production and 46% of the total cereal production of the country. It is the staple food of more than 60% of the world's population especially for most of the people of South-East Asia.

Submergence stress is a major constraint to rice production during the monsoon flooding season in the rainfed lowlands in south and southeast Asia, which causes annual losses of over US$1 billion and affects disproportionately the poorest farmers in the world (Dey and Upadhyaya, 1996; Xu *et al.*, 2006) [2]. Excessive flooding poses risks to human life and is a major contributor to the poverty and vulnerability of marginalized communities especially women and children in poor families. It is estimated that the flood-affected area has more than doubled in size from about 5% (19 million hectares) to about 12% (40 million hectares) of India's geographic area (World Bank Report, 2008). During submergence, plant survival is greatly affected by depth of water and by its physico-chemical characteristics (oxygen and carbon dioxide concentration, pH, turbidity, temperature, etc.). Low oxygen stress in plants can occur during flooding and compromise the availability and utilization of carbohydrates in root and shoot tissues. Low-oxygen-tolerant rice and- sensitive rice plants were analyzed under anaerobiosis in light to evaluate main factors of the primary metabolism that affect sensitivity against oxygen deprivation: activity of glycolysis and the rate of photosynthesis.

Materials and Methods

The present investigation was carried out in Kharif season, during 2014-2015 at the Research Farm of Department of Crop Physiology, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P.) India. Experiment was conducted in complete randomized design with three replications in submergence pond (pond size; 20x10x1.25 M). Field was prepared and 40 seeds of each genotype were (row length 2 meter) direct seeded in row. Pond (field) was filled up with drain water up to height in 20-25 cm to create anaerobic condition and water depth was maintained for 30 days. Number of seeds germinated was counted and germination% was calculated. For pot culture, same set of genotypes were used for validation of field data. Sixty pots were taken and ten kg capacity polythene bags filled with the well sieved soil were placed in all the pots to protect drainage of water. Ten seeds of each genotype were sown in each pot with three replication. Pots were placed into the pond filled with water up to 40 cm and maintained for 30 days to create anaerobic condition. Three plants of each pot were selected and different growth parameters were recorded. For Laboratory screening (Petridisc), same set of genotypes were used for study of above parameters in normal condition. Hundred petridisc (150×15 mm) were taken and 10 seeds of each entry repeated five times soaked with tap water are used. Petridisc kept at room temperature and allowed to germinate after germination different parameters were recorded. To calculate germination percentage, seeds with radicle emergence 2 mm length were counted and germination percentage was calculated with the following formula

$$\text{Germination (\%)} \quad \frac{\text{Number of seeds germinated}}{\text{Total no. of seeds placed}} = \text{x } 100$$

Leaf area was calculated from 1st to 5th day after de-submergence and leaf elongation was calculated by using leaf length.

$$\text{Shoot elongation} = \frac{\text{Final shoot length} - \text{Initial length}}{5}$$

Results and Discussions

Data pertaining to the germination of seeds under various conditions have been presented in the table 1. NDR-9516 and NDR-9467 has been reported maximum germination percentage (100%) followed by NDR-9503 (96.67%) and minimum was noted in NDR-8588 (53.33%) under aerobic condition. Data regarding anaerobic condition incorporated in table 4.1 showed maximum germination percentage in NDR-9930111 (60 %) followed by NDR-8522-2 (43%) while minimum germination percentage was noted in NDR-9503 (5-10%). Other genotypes showed less than 40% germination under anaerobic condition either tested in pot culture or field condition.

Data presented in table 2 shows that coleoptile length increases with the increase in time but the maximum coleoptiles length was noted in NDR-9503 followed by NDR-8532 and minimum coleoptile length was noted in NDR-8555 time frame measurement whereas maximum coleoptile elongation was noted in IR-64 (1.18) followed by NDR-9467 (0.94) and the minimum coleoptile elongation was noted in NDR-8555 (0.16).

Data with respect to the shoot elongation is presented in table 3 indicates that maximum shoot elongation was recorded in NDR-9730018 and followed by NDR-8602 where as the minimum shoot elongation was marked in NDR-9930112 during anaerobic treatment.

Out of twenty, fifteen had higher germination percent (>80%) while five entries showed poor germination percent (<70%) where as under anaerobic condition germination was hampered in all genotypes, only NDR-9930111 showed 60 and 55% anaerobic germination in pot culture and field condition respectively. Some other genotypes i.e. NDR-8522-2, NDR-9930112 and NDR-8610 also showed better germination (>40%) in anaerobic condition.

Tolerance to anaerobic conditions during germination is a complex trait controlled by several families of genes that are involved in essential processes such as breakdown of starch, glycolysis fermentation and other biochemical and metabolic processes (Bailey-serres and Chang 2005; Ismail *et al.,* 2009) [1, 3]. The breakdown of starch is a complex biochemical process modulated by both hormonal and metabolic regulations (Perata *et al.,* 1997) [5]. Amylases are the key enzymes for starch degradation in germinating seeds and rice varieties that have greater ability to degrade starch even under oxygen degradation through successful production of alpha amylase are more likely to vigorously germinate and survive the stress (Loreti *et al.,* 2003) [4]. Key enzyme in the alcoholic fermentation pathway, alcohol dehydrogenase (ADH) and pyruvate decorboxylase (PDC) are induced by anoxia stress. This pathway recycles nicotina mide adenine dinucleotide (NAD) to maintain glycolysis and substrate level phosphorylation which could provide energy for successful germination through coleoptile elongation in the absence of oxygen.

Table 1: Germination % of different genotypes under different condition

Varieties	Germination %		
	Aerobic condition	Pot condition	Field condition
NDR-9503	96.67	10.00	5.00
NDR-8555	76.67	16.67	6.67
NDR-8820	60.00	16.67	13.33
NDR-8610	63.33	33.33	36.67
NDR-8588	53.33	16.67	15.33
NDR-9516	100.00	23.33	19.17
NDR-8602	70.00	20.00	15.00
NDR-9453	96.67	33.33	32.50
NDR-9460	80.00	36.67	21.67
NDR-9521	90.00	26.67	22.50
NDR-8532	90.00	33.33	26.67
NDR-8016	93.33	16.67	6.67
NDR-9479	90.00	33.33	30.83
NDR-9930112	86.67	43.33	40.83
NDR-8846-2	63.33	33.33	25.00
NDR-8522-2	83.33	43.33	33.50
NDR-9467	100.00	13.33	5.00
IR-64	86.67	20.00	15.83
NDR-9930111	90.00	60.00	55.00
NDR-9730018	93.33	13.33	6.67
SEm±	6.28	26.17	13.39
CD at 5%	17.95	52.89	27.06

Table 2: Coleoptile elongation of different genotypes *in vitro* condition

Varieties	Coleoptile length (mm d^{-1})					Coleoptile elongation (mm d^{-1})
	3rd day	4th day	5th day	6th day	7th day	
NDR-9503	2.10	3.83	4.10	4.80	6.32	0.65
NDR-8555	0.25	1.06	1.60	1.31	1.44	0.16
NDR-8820	1.40	1.82	2.97	2.55	3.48	0.41
NDR-8610	0.83	1.10	3.20	3.12	3.68	0.55
NDR-8588	0.74	2.20	2.27	3.50	5.00	0.87
NDR-9516	1.26	2.37	2.82	3.05	3.90	0.54
NDR-8602	0.65	1.37	1.96	2.28	2.61	0.40
NDR-9453	1.47	2.31	3.20	4.40	4.89	0.80
NDR-9460	1.33	2.33	2.80	3.28	4.80	0.71
NDR-9521	1.62	2.03	3.50	3.65	4.34	0.55
NDR-8532	1.19	2.46	3.51	4.70	5.44	0.77
NDR-8016	1.93	2.02	3.11	4.38	4.66	0.56
NDR-9479	0.46	1.65	2.54	3.66	4.25	0.72
NDR-9930112	0.37	2.08	3.03	3.75	4.80	0.90
NDR-8846-2	0.37	2.01	2.46	3.31	5.49	0.90
NDR-8522-2	0.57	1.81	3.38	4.41	4.63	0.84
NDR-9467	0.77	1.65	3.44	4.25	5.16	0.94
IR-64	0.80	1.42	3.49	4.61	5.40	1.18
NDR-9930111	0.50	1.50	2.38	3.71	4.95	0.91
NDR-9730018	0.60	1.57	2.57	3.47	4.37	0.73
SEm±	0.045	0.090	0.143	0.149	0.204	0.54
CD at 5%	0.128	0.257	0.407	0.425	0.584	1.10

Table 3: Shoot elongation in direct seeded rice grown under anaerobic condition (20-25 cm water depth maintained upto 30 DAS)

Varieties	Shoot elongation under anaerobic condition (mm d^{-1})				
	1st day	2nd day	3rd day	4th day	5th day
NDR-9503	0.50	0.51	0.52	0.53	0.54
NDR-8555	0.37	0.38	0.40	0.42	0.44
NDR-8820	0.63	0.65	0.66	0.67	0.68
NDR-8610	0.50	0.52	0.54	0.56	0.58
NDR-8588	0.44	0.45	0.46	0.48	0.50
NDR-9516	0.36	0.37	0.39	0.40	0.42
NDR-8602	0.65	0.66	0.67	0.69	0.74
NDR-9453	0.64	0.65	0.65	0.67	0.68
NDR-9460	0.45	0.46	0.46	0.47	0.48
NDR-9521	0.63	0.65	0.65	0.68	0.70
NDR-8532	0.54	0.55	0.57	0.58	0.60
NDR-8016	0.36	0.37	0.38	0.40	0.42
NDR-9479	0.38	0.39	0.40	0.42	0.43
NDR-9930112	0.31	0.34	0.39	0.39	0.40
NDR-8846-2	0.63	0.64	0.66	0.67	0.69
NDR-8522-2	0.66	0.68	0.69	0.71	0.71
NDR-9467	0.52	0.54	0.53	0.58	0.61
IR-64	0.55	0.57	0.58	0.60	0.61
NDR-9930111	0.57	0.58	0.60	0.61	0.62
NDR-9730018	0.68	0.70	0.72	0.73	0.79
SEm±	0.020	0.020	0.021	0.021	0.021
CD at 5%	0.057	0.058	0.060	0.059	0.059

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