Original Research Article

Identification and Evaluation of rice (*Oryza sativa* L.) genotypes/ varieties for drought tolerance : Growth & Yield Approaches

Abstract

The investigation entitled "Identification and evaluation of rice (*Oryza sativa* L.) genotypes/ varieties for drought tolerance: growth & yield approaches" was conducted during *Kharif* season, 2020-21 and 2021-22 at the field of Student's Instruction Farm, Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya-224 229 (Uttar Pradesh). Twelve elite rice genotypes were shown in RBD with three replications and morphological data recorded were plant height at maturity, Tiller number per plant, Flag leaf area (cm), Fresh weight plant^{-1}(gm), Dry weight plant^{-1}(gm), Relative Water Content (%), Panicle Bearing Tiller, Panicle length (cm), Grain yield plant^{-1}(gm). Among the genotypes highest plant height was observed in Nagina 22 comparatively to lowest was found in NDR 97 under drought condition. The flag leaf area also affected in drought stress. Drought stress also affected the tiller number/ plant and panicle bearing/ plants during drought stress. During during drought stress condition, panicle length of Nagina 22, Sahbhagi Dhaan and Sukha Dhaan also affected. Under drought stress condition, relative water content also affected from genotype to genotype. Under the drought condition, Nagina 22, Sushk Samrat and Sukha Dhaan performed well for yield/ plant values of 1.81, 1.75 and 1.36g respectively. Result suggested that plant height and yield/ plant can be used as selection indices for drought tolerance. The abstract should be concise and informative. It should briefly describe the purpose of the work, techniques and methods used, major findings with important data and conclusions. No references should be cited in this part. Generally non-standard abbreviations should not be used, if necessary they should be clearly defined in the abstract, at first use.

Keywords: height, rice, flag leaf area, relative water content, grain, panicle, yield

Introduction:

Rice (*Oryza sativa* L.) is one of the most consumed staple food crops worldwide. In developing countries, people often rely on rice as their sole of nutrition (Yang *et al.,* 2016). It is important cereals crops be grown in any part of the world. Drought, one of the environmental stresses, is the most significant factor restricting plant growth and crop productivity in the majority of agricultural fields of the world (Tas and Tas, 2007). References must be listed at the end of the manuscript and numbered in the order that they appear in the text. In the text, citations should be indicated by the reference number in brackets. Rice is grown in more than a hundred countries, with a total harvested area of approximately 158 million hectares, contributes about 40 to 43% of total food grain production, and continues to play wide role in the national food and livelihood security system. The total production of rice in 2021-22 is 127.92 mt and the area is covered 46mha. (Anonymous, 2022) References must be listed at the end of the manuscript and numbered in the order that they appear in the text. In the text, citations should be indicated by the reference number in brackets.

Approximately 7.5 % of total rice production in world comes from irrigated lowlands (Bouman and Tung, 2001). Biotic and abiotic factors are limited to adversely the productivity of the rice-growing areas of the world. It has been estimated that approximately more than 200 million tons of rice are lost every year due to environmental stresses, diseases, and insect pests (Chen *et al.*, 2013). Drought, a period of no rainfall or irrigation that affects plant growth, is a major constraint for about 50% of the world production area of rice (Khush, 2005). Drought effects in lowland rice can occur when soil water contents drop below saturation (Bouman and Tung, 2001). Some researchers reported that rice crops are vulnerable to drought, which causes large yield losses in many Asian countries (Bouman and Tung 2001). For molecular approaches to be useful there must be genetic variation for the specified traits within inter-breeding genotypes, a linkage must be established between the trait and suitable marker(s) and there must be a reliable technique to screen out for the specific trait. Drought stress decreases the rate of photosynthesis by decreasing pigments, photosystems, gas exchange, and key photosynthetic enzymes, thus affecting various steps in the photosynthetic pathway (Asharf and Harris, 2013), and this will ultimately reduce plant biomass and yield. Development of molecular markers and their use for the genetic dissection of agronomical important traits has become a powerful approach for studying the inheritance of complex plant traits such as drought tolerance (Suji *et al*., 2011).

Drought stress leads to stomatal closure leading to limitation of gaseous exchange. The closure of stomata is controlled by phytohormones such as abscisic acid, cytokinins, etc. Reduction of the water content reduces several stomatal activity and cell growth. Leaf area, cell size, and intercellular volume decrease, and leaf rolling and death of leaf results from drought stress. In roots, drought results in a reduction of meristematic activity, arresting root elongation. Suberization of the root system can also results from water stress (Singh *et al*., 2012). Water deficit affect nearly all plant growth processes. Moisture stress affect rice Morphological characters like germination, plant height, plant biomass, number of tillers and various root and leaf traits, physiological characters like reduce photosynthesis, transpiration, stomatal conductance, relative water content, chlorophyll content, photosystem II activity, membrane stability and permeability, and abscisic acid content, biochemical characters, like accumulation of various osmoprotectance (proline, sugar, polyamines and antioxidants etc. (Kumari *et al*., 2019).

Materials and Methods: The present investigation entitled "Identification and evaluation of rice (*Oryza sativa* L.) genotypes/ varieties for drought tolerance: growth & yield approaches" was conducted at Student Instructional farm at Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya (U.P.), India during *Kharif* season of 2020-21 and 2021-22. Twelve genotypes (Sukha Dhaan, DRR 44, DRR 42, Sahbhagi Dhaan, NDR 97, Sushk Samrat, IR 64, NDR 102, Nagina 22, NDR 359, NDR 2064, NDR 2065) were used. The experiment was conducted in polyhouse at Department of Plant Molecular Biology & Genetic Engineering, College of Agriculture, Acharya Narendra University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.). Rice seeds were sown in plastic pots having length and width of 45.96 cm and 27.94 cm, respectively. Five plants were maintained in pots after germination. Five pots per replication or twenty five plants per replication were used for data collection of genotypes. Two water regimes were used: irrigated (control) and water stress condition using with five (5) replications. The 14 days drought treatment during reproductive stage of rice plants were imposed on 80 days of old plants. The stressed plants were irrigated at leaf rolling to prevent plants from complete drying. At the time of maturity data was collected for traits like plant height (cm), tillers/ plant, flag leaf area (cm^2), panicle length (cm), number of grains/ plant (g), yield/ plant (gm).

Results and Discussion:

1. **Plant height at maturity (cm):**

   Data regarding to plant height of different rice genotypes under irrigated normal field condition at maturity stage are presented in (Table 1). Plant height at maturity ranging from 89.60cm to 128.36cm in which the maximum plant height was observed in Nagina-22 (128.36) cm fallowed by NDR- 2064 (128.26 cm) & Sukha Dhaan (127.63 cm). The minimum plant height was recorded in Narendra-97 (89.60 cm) followed by NDR 102 (103.36 cm) & DRR 44 (111.33 cm). Data regarding plant height in drought stress condition at maturity given in (Table 1). The data revealed that plant height at maturity ranged from 71.15cm to 105.28cm in which highest plant height was recorded in Nagina-22 (105.28 cm) followed by Sukha Dhaan (101.33 cm) & NDR 2065 (95.34 cm). The lowest plant height was recorded in Narendra-97 (71.15 cm) followed by IR 64 (65.28 cm) & NDR 102 (85.45 cm).

Table. 1 Effect of drought on plant height of rice genotypes

S.No.	Genotypes	Control	Stress	Percent Reduction
1.	Sukha Dhaan	127.23	101.33	20.36
2.	DRR 44	111.33	90.51	18.70
3.	DRR 42	116.7	91.57	21.53
4.	Sahbhagi Dhaan	127.63	94.69	25.81
5.	NDR 97	89.6	71.15	20.59
6.	Sushk Samrat	126.01	94.77	24.79
7.	IR 64	103.36	75.58	26.88
8.	NDR 102	123.26	85.45	30.67
9.	Nagina 22	128.36	105.28	17.98
10.	NDR 359	118.66	91.54	22.86
11.	NDR 2064	128.26	95.19	25.78
12.	NDR 2065	123.2	95.34	22.61
	Grand Mean	118.63	91.05	
	Min.	89.60	71.15	
	Max.	128.36	105.28	
	C.V.	1.49	1.01	
	SEm±	1.02	0.41	
	C.D.	3.02	1.17	

2. **Tiller number plant^{-1} (count):**

Data regarding to tiller number plant^{-1} of different rice genotypes under irrigated normal field condition are presented in (Table 2). Tiller number ranging from 14.00 to 19.00 in which the maximum tiller number was observed in Nagina-22 (19.00) followed by Sahbhagi Dhaan (18.00) & Sushk Samrat (17.00). The minimum tiller number was recorded in DRR 44 & NDR 102 (14.00) followed by Sukha Dhaan & IR 64 (15.00) & DRR 42, NDR 359, NDR 2064, NDR 2065 & NDR 97 (16.00). Data regarding tiller number plant^{-1} in drought stress condition are given in (Table 2). The data revealed that tiller number ranging from 8.00 to 15.00 in which highest tiller number was recorded in Nagina-22 (15.00) followed by DRR 42, Sahbhagi Dhaan, NDR 359, NDR 2065 (12.00) & Sukha Dhaan (11.00). The lowest tiller number was recorded in IR 64 (8.00) followed by DRR 44, NDR 102 (9.00) & NDR 2064 (10.00).

Table.2 Effect of drought on tiller number of rice genotypes

S.No.	Genotypes	Control	Stress	Percent Reduction
1.	Sukha Dhaan	15.00	11.00	26.67
2.	DRR 44	14.00	9.00	35.71
3.	DRR 42	16.00	12.00	25.00
4.	Sahbhagi Dhaan	18.00	12.00	33.33
5.	NDR 97	16.00	10.00	37.50
6.	Sushk Samrat	17.00	12.00	29.41
7.	IR 64	15.00	8.00	46.67
8.	NDR 102	14.00	9.00	35.71
9.	Nagina 22	19.00	15.00	21.05
10.	NDR 359	16.00	12.00	25.00
11.	NDR 2064	16.00	10.00	31.25
12.	NDR 2065	16.00	12.00	25.00
	Grand Mean	16.41	11.08	
	Min.	14.00	8.00	
	Max.	19.00	15.00	
	C.V.	3.90	10.01	
	SEm±	0.38	0.54	
	C.D.	1.12	2.25	

3. **Flag Leaf Area (cm^2)**

Data regarding to flag leaf area of different rice genotypes under irrigated normal field condition are presented in (Table 3). Flag leaf area ranging from 26.79cm^2 to 41.17 cm^2 in which the maximum flag leaf area was observed in Nagina-22 (41.17 cm^2) followed by NDR 2064 (41.08 cm^2) & NDR 2065 (40.62 cm^2). The minimum flag leaf area was recorded in DRR 44 (26.79 cm^2) followed by NDR 97 (27.93 cm^2) & NDR 102 (29.58 cm^2). Data regarding flag leaf area in drought stress condition are given in (Table 3). The data revealed that flag leaf area ranging from 22.95cm^2 to 36.20cm^2 in which highest flag leaf area was recorded in Nagina-22 (36.20 cm^2) followed by NDR 2065 (35.84 cm^2) & NDR 2064 (35.56 cm^2). The minimum flag leaf area was recorded in DRR 44 (22.95 cm^2) followed by NDR 97 (24.38 cm^2) & NDR 102 (24.52 cm^2).

Table. 3 Effect of drought on flag leaf area of rice genotypes

S.No.	Genotypes	Control	Stress	Percent Reduction
1.	Sukha Dhaan	30.01	25.55	14.83
2.	DRR 44	26.79	22.95	14.41
3.	DRR 42	35.36	28.75	18.69
4.	Sahbhagi Dhaan	40.28	34.44	14.50
5.	NDR 97	27.93	24.38	12.71
6.	Sushk Samrat	35.78	31.6	11.68
7.	IR 64	40.28	31.6	21.55
8.	NDR 102	29.58	24.52	17.11
9.	Nagina 22	41.17	36.2	12.07
10.	NDR 359	36.1	32.22	10.75
11.	NDR 2064	41.08	35.56	13.44
12.	NDR 2065	40.62	35.84	11.77
	Grand Mean	35.41	30.29	
	Min.	26.79	22.95	
	Max.	41.17	36.20	
	C.V.	1.89	3.68	
	SEm±	0.38	0.52	
	CD	1.14	1.49	

4. **Fresh Biomass Plant^{-1} (gm):**

Data regarding to fresh biomass plant^{-1} of different rice genotypes under irrigated normal field condition are presented in (Table 4). Fresh biomass ranging from 63.37gm to 71.01gm in which the maximum fresh biomass was observed in Nagina-22 (71.01 gm) followed by NDR 2064 (69.44 gm) & NDR 2065 (69.36 gm). The minimum fresh biomass was recorded in NDR 97 (63.37 gm) followed by IR 64 (65.81 gm) & DRR 42 (66.52 gm). Data regarding fresh biomass in drought stress condition are given in (Table 4). The data revealed that fresh biomass ranged from 48.03gm to 63.81gm in which highest fresh biomass was recorded in Nagina-22 (63.81 gm) followed by NDR 359 (61.73 gm) & NDR 2065 (61.58 gm). The lowest fresh biomass was recorded in DRR 44 (48.03 gm) followed by NDR 97 (51.81 gm) & IR 64 (52.19 gm).

Table. 4 Effect of drought on fresh biomass of rice genotypes

S.No.	Genotypes	Control	Stress	Percent Reduction
1.	Sukha Dhaan	70.24	55.44	21.07
2.	DRR 44	67.16	48.03	28.48
3.	DRR 42	66.52	52.26	21.44
4.	Sahbhagi Dhaan	67.43	60.31	10.56
5.	NDR 97	63.37	51.81	18.24
6.	Sushk Samrat	69.17	56.44	18.40
7.	IR 64	65.81	52.19	20.70
8.	NDR 102	66.51	56.07	15.70
9.	Nagina 22	71.01	63.81	10.14
10.	NDR 359	68.77	61.73	10.24
11.	NDR 2064	69.44	57.63	17.01
12.	NDR 2065	69.36	61.58	11.22
	Grand Mean	67.89	56.44	
	Min.	63.37	48.03	
	Max.	71.01	63.81	
	C.V.	3.67	10.01	
	SEm±	1.42	2.55	
	C.D.	4.21	7.29	

5. **Dry Biomass Plant^{-1} (gm):**

Data regarding to dry biomass plant^{-1} of different rice genotypes under irrigated normal field condition are presented in (Table 5). Dry biomass ranging from 21.65gm to 26.66gm in which the maximum dry biomass was observed in Nagina-22 (26.66 gm) followed by NDR 2064 (25.66 gm) & DRR 44 (25.61 gm). The minimum dry biomass was recorded in Sushk Samrat (21.65 gm) followed by IR 64 (21.94 gm) & NDR 97 (22.76 gm). Data regarding dry biomass in drought stress condition are given in (Table 5). The data revealed that dry biomass ranged from 17.65gm to 24.17gm in which highest dry biomass was recorded in Nagina-22 (24.17 gm) followed by Sukha Dhaan (22.66 gm) & NDR 2064 (21.66 gm). The minimum dry biomass was recorded in NDR 97 (17.65 gm) followed by NDR 102 (17.89 gm) & IR 64 (18.01 gm).

Table. 5 Effect of drought on dry biomass of rice genotypes

S.No.	Genotypes	Control	Stress	Percent Reduction
1.	Sukha Dhaan	25.46	22.66	10.96
2.	DRR 44	25.61	18.54	27.61
3.	DRR 42	25.05	20.56	17.92
4.	Sahbhagi Dhaan	23.59	20.92	11.32
5.	NDR 97	22.76	17.65	22.45
6.	Sushk Samrat	21.65	19.34	10.67
7.	IR 64	21.94	18.01	18.37
8.	NDR 102	25.89	17.89	30.90
9.	Nagina 22	26.66	24.17	9.34
10.	NDR 359	23.09	18.98	17.80
11.	NDR 2064	25.66	21.66	15.59
12.	NDR 2065	22.76	19.37	14.89
	Grand Mean	24.17	19.97	
	Min.	21.65	17.65	
	Max.	26.66	24.17	
	C.V.	5.03	5.82	
	SEm±	0.70	0.52	
	CD	2.07	1.51	

6. **Relative Water Content (%):**

Data regarding to relative water content of different rice genotypes under irrigated normal field condition are presented in (Table 6). Relative water content ranging from 80.92% to 89.92% in which the maximum relative water content was observed in Sukha Dhaan (89.92%) followed by IR 64 (89.72%) & NDR 2065 (85.16%). The minimum relative water content was recorded in NDR 359 (80.92%) followed by NDR 97 (81.21%) & Sahbhagi haan (81.69%). Data regarding relative water content in drought stress condition are given in (Table 6). The data revealed that relative water content ranging from 62.33% to 65.42% in which highest relative water content was recorded in Nagina-22 (65.42%) followed by NDR 2064 (65.38%) & Sushk Samrat (65.09%). The lowest relative water content was recorded in IR 64 (63.33%) followed by NDR 102 (63.94%) & Sukha Dhaan (64.53%).

Table. 6 Effect of drought on relative water content of rice genotypes

S.No.	Genotypes	Control	Stress	Percent Reduction
1.	Sukha Dhaan	89.92	64.53	24.69
2.	DRR 44	83.88	65.15	22.33
3.	DRR 42	84.1	64.93	22.79
4.	Sahbhagi Dhaan	81.69	64.95	20.49
5.	NDR 97	81.21	64.73	20.29
6.	Sushk Samrat	84.97	65.09	23.40
7.	IR 64	85.69	62.33	30.68
8.	NDR 102	84.76	63.94	24.56
9.	Nagina 22	81.71	65.42	19.94
10.	NDR 359	80.92	64.78	19.96
11.	NDR 2064	82.48	65.38	20.73
12.	NDR 2065	85.16	64.7	24.03
	Grand Mean	83.87	64.66	
	Min.	80.92	62.33	
	Max.	89.92	65.42	
	C.V.	3.65	0.71	
	SEm±	1.75	0.26	
	CD at 5%	5.17	0.78	

7. **Panicle Bearing Tillers (count) :**

Data regarding to panicle bearing tiller of different rice genotypes under irrigated normal field condition are presented in (Table 7). Panicle bearing tiller number ranging from 12.00 to 19.00 in which the maximum tiller number was observed in Nagina-22 (19.00) followed by NDR 359 (18.00) & Sukha Dhaan (17.00). The minimum panicle bearing tiller was recorded in DRR 44 (12.00) followed by DRR 42, Sahbhagi Dhaan, NDR 97, Sushk Samrat (13.00) & NDR 2064 (14.00). Data regarding panicle bearing tiller in drought stress condition are given in (Table 7). The data revealed that panicle bearing tiller ranging from 4.00 to 11.00 in which highest panicle bearing tiller was recorded in Nagina-22 (11.00) followed by Sukha Dhaan (9.00) & NDR 359 (7.00). The lowest panicle bearing tiller was recorded in NDR 97 (4.00) & followed by IR 64 & NDR 102 (5.00) & DRR 44 & DRR 42 (6.00).

Table. 7 Effect of drought on panicle bearing tillers of rice genotypes

S.No.	Genotypes	Control	Stress	Percent Reduction
1.	Sukha Dhaan	17.00	9.00	47.06
2.	DRR 44	12.00	6.00	50.00
3.	DRR 42	13.00	6.00	53.85
4.	Sahbhagi Dhaan	13.00	7.00	46.15
5.	NDR 97	13.00	4.00	69.23
6.	Sushk Samrat	13.00	7.00	46.15
7.	IR 64	13.00	5.00	61.54
8.	NDR 102	12.00	5.00	58.33
9.	Nagina 22	19.00	11.00	42.11
10.	NDR 359	18.00	8.00	55.56
11.	NDR 2064	14.00	7.00	50.00
12.	NDR 2065	13.00	7.00	46.15
	Grand Mean	14.16	6.84	
	Min.	12.00	4.00	
	Max.	19.00	11.00	
	C.V.	5.82	27.43	
	SEm±	0.48	0.82	
	CD at 5%	1.42	2.35	

8. **Panicle Length (cm) :**

Data regarding to panicle length of different rice genotypes under irrigated normal field condition are presented in (Table 8). Panicle length ranging from 20.76cm to 29.14cm in which the maximum panicle length was observed in DRR 42 (29.14 cm) followed by NDR 359 (28.51 cm) & NDR 2064 (26.77 cm). The minimum panicle length was recorded in NDR 97 (20.76 cm) followed by Sushk Samrat (21.77 cm) & Sukha Dhaan (21.80 cm). Data regarding panicle length in drought stress condition are given in (Table 8). The data revealed that panicle length ranging from 11.42cm to 20.12cm in which highest panicle length was recorded in Nagina-22 (20.12 cm) followed by Sahbhagi Dhaan (18.29 cm) & Sukha Dhaan (17.79 cm). The lowest panicle length was recorded in IR 64 (11.42 cm) followed by NDR 102 (13.02 cm) & NDR 97 (15.21 cm).

Table. 8 Effect of drought on panicle length of rice genotypes

S.No.	Genotypes	Control	Stress	**Percent Reduction**
1.	Sukha Dhaan	21.82	17.79	18.39
2.	DRR 44	25.63	16.67	34.96
3.	DRR 42	29.14	18.29	37.23
4.	Sahbhagi Dhaan	23.93	16.56	30.80
5.	NDR 97	20.76	15.21	30.15
6.	Sushk Samrat	21.77	15.24	26.59
7.	IR 64	25.36	11.42	54.97
8.	NDR 102	26.22	13.02	50.31
9.	Nagina 22	26.33	20.12	23.59
10.	NDR 359	28.51	15.16	46.81
11.	NDR 2064	26.77	15.55	41.89
12.	NDR 2065	26.33	15.54	40.98
	Grand Mean	25.20	15.88	
	Min.	20.76	11.42	
	Max.	29.14	20.12	
	CV	3.04	28.53	
	SE(m)±	0.44	1.85	
	C.D.	1.30	5.31	

9. **Grain Yield Plant^{-1} (gm):**

Data regarding to grain yield plant^{-1} of different rice genotypes under irrigated normal field condition are presented in (Table 9). Grain yield ranging from 46.78gm to 60.75gm in which the maximum grain yield was observed in Sahbhagi Dhaan (60.75 gm) followed by Nagina 22 (59.85 gm) & NDR 2064 (59.32 gm) . The minimum grain yield was recorded in Sukha Dhaan (47.78 gm) followed by Sushk Samrat (47.51 gm) & IR 64 (53.44 gm). Data regarding grain yield in drought stress condition are given in (Table 9). The data revealed that grain yield ranged from 1.06gm to 1.81gm in which highest grain yield was recorded in Nagina-22 (1.81 gm) followed by Sushk Samrat (1.75 gm) & Sukha Dhaan (1.36 gm). The lowest grain yield was recorded in DRR 42 (1.06 gm) followed by NDR 102 (1.29 gm) & NDR 97 (1.31 gm).

Table. 9 Effect of drought on grain yield of rice genotypes

S.No.	Genotypes	Control	Stress	Percent Reduction
1.	Sukha Dhaan	46.78	1.36	97.09
2.	DRR 44	55.33	1.34	97.58
3.	DRR 42	56.43	1.06	98.12
4.	Sahbhagi Dhaan	60.75	1.35	97.78
5.	NDR 97	58.68	1.31	97.77
6.	Sushk Samrat	47.51	1.75	96.32
7.	IR 64	53.44	1.80	96.63
8.	NDR 102	57.13	1.29	97.74
9.	Nagina 22	59.85	1.81	96.98
10.	NDR 359	55.99	1.34	97.61
11.	NDR 2064	59.32	1.35	97.72
12.	NDR 2065	55.18	1.34	97.57
	Grand Mean	55.49	1.38	
	Min.	46.78	1.06	
	Max.	60.75	1.81	
	C.V.	0.92	122.8	
	SEm±	0.27	10.03	
	C.D.	0.87	28.58	

Conclusion: Drought stress had influence on yield and yield contributing traits in rice. Nagina 22 & Sahbhagi Dhaan showed high yield under drought stress along with Panicle bearing tillers, number of grains/panicle, this suggested that the genotype possessed genes for the high expression of their respective genes i.e. panicle bearing tillers, number of grains/ panicle. Whereas, Nagina 22 and NDR 2064 both genotypes performed well under normal conditions. The traits number of grains/panicle, plant height and grain were associated with plant yield and had either high direct or indirect effect and could be exploited for selection of desirable genotypes. Such genotypes can be exploited in the breeding program designed for evolving high yielding and drought tolerant rice cultivars.

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