LUPINE PUBLISHERS
Open Access

Current Investigations in Agriculture and Current Research

DOI: 10.32474/CIACR.2018.03.000171

ISSN: 2637-4676

Research Article

Yield Stability of Very Early Rice Genotypes Under Rainfed Upland Ecosystem

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Received: July 01, 2018; **Published:** July 18, 2018

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Abstract

A field experiment was carried out at All India Coordinated Research Project for Dryland Agriculture, Orissa University of Agriculture and Technology, Phulbani to evaluate the newly developed early maturing rice genotypes and estimate their yield stability. The trial was laid out in randomized block design with three replications for 5 years from 2012 to 2016 involving 26 rice genotypes including-(a) 22 improved lines from AICRP for Dryland Agriculture, OUAT, Phulbani (ODR lines; ODR denotes 'Odisha dryland rice'), (b) one line from NRRI sub-centre, Hazaribag, DDR-121, (c) one exotic variety, ZHU 11-26 and (iv) two varieties from NRRI, Cuttack, Vandana and N-22. Another set of experiment was carried out at ICAR-National Rice Research Institute, Cuttack to evaluate the response of the genotypes towards drought stress. Highest mean grain yield was recorded in ODR 12-3 (30.43 q/ha) followed by ODR 12C (27.42 q/ha) and ODR 41 (27.22 q/ha). ODR 12C exhibiting high mean yield along with highest slope can be considered most adaptable. Long slender aromatic genotypes such as ODR 1, ODR 1-1, ODR 1-2 and ODR 1-3 had also high yield coupled with slope >1.0, thus exhibited high stability. Drought score (DS), performed on the basis of Standard Evaluation System (SES) scale, showed that ODR-55(1) is highly drought tolerant on the basis of leaf rolling and drying character (SES=0).

Keywords: Rice; Rainfed; Drought score; Yield stability

Introduction

Rice is the staple food for over 90% population of the Asiatic countries. It is the principal source of energy for the people of Asia, Latin America and pacific islands [1]. It has a distinct position among cereal crops due to its capacity for being cooked and consumed as whole grains [2] and quality assumes great significance. It is also the source of livelihood for a majority of people of India, China and some other countries. Rice cultivation is one of the major providers of rural employment. However, shortage of water in many rices growing countries of the world is gradually increasing with simultaneous decrease in crop yield [3]. Upland rice, covering over 9 million hectares in Asia, is subjected to multiple abiotic stresses, drought being the number one, occurring almost regularly, limiting crop productivity and farmers' income. In this context, increasing productivity of rice in all eco-systems assumes a great challenge as one-sixth of the global population is deprived of enough food and remains hungry or under-nourished.

Since the commencement of green revolution during late 1960s, rice production in India has become trebled and it is important to maintain the increasing trend in future. However, rice cultivation is considered non-remunerative in many parts of India particularly in rainfed uplands due to frequent crop failure during long dry spells. Still then, in several locations of the states like Odisha, West Bengal, Chhatisgarh, etc. people are reluctant for crop diversification in uplands during kharif (S-W monsoon) season and traditionally grow rice. Many farmers use local short durational rice varieties which mature in 80-90 days and escape terminal drought. In years with early or mid-season drought, these varieties fail to give satisfactory yield. Again, long slender scented rice varieties which could fetch high market price are not available for upland situation.

Rice is the main crop of Odisha including hilly districts like Kandhamal and is grown in all types of land. In Kandhamal district, 80% of the cultivated area is upland without irrigation facility where only short durational drought tolerant/escaping genotypes can be grown. The productivity of local variety is low. In N-E ghat zone of Orissa, the annual rainfall is quite high (above 1400mm), but the distribution is quite erratic and dependable monsoon occurs only for 3 months. Due to sandy/sandy-loam soil texture in uplands, rice crop suffers severely from dryspells lasting for a week. Again, the yield and quality of local type of rice grown in uplands of Kandhamal is not so good from marketing point of view. Thus, availability of short durational, drought tolerant, high yielding and good quality rice variety which will be acceptable by the farmers is needed to increase the net income. Therefore, crop improvement programmes were initiated at All India Coordinated Research Project for Dryland Agriculture from 2006-07 to develop suitable rice varieties for rainfed upland system. The present investigation highlights the yield stability of twenty-six rice genotypes suitable for upland with required features like 1. Short duration, 2. Long slender aromatic grain (Basmati type), 3. High yield, 4. Drought tolerance, and/or 5. Disease pest resistance in order to assure high and stable yield as well as better price for the produce.

Materials and Methods

Site description: The soil at the experimental site had Sandy-loam Texture with pH 5.22 and average N, P_2O_5 and K_2O content of 123, 32.1 and 164.9kg/ha, respectively. The normal rainfall of the location is 1407.34mm. The annual and cropping season rainfall with dry spells affecting growth and productivity at the experimental site in different years has been presented in Table 1.

Table 1: Rainfall at Experimental site with dry spells.

Year	Annual rainfall (mm)	Crop season rainfall (mm)	Periods of dry spells affecting crop growth
2012	1695.6 mm	1250 mm	No rainfall from 24th Sep. to 1st Oct. coinciding with flowering or maturity stage of different varieties
2013	1363.4 mm	597.8 to 792.6 mm	Dryspells from 2-5 Aug. (4 days), 14-18 Aug. (5 days), 22-26 Aug. (5 days), 30 Aug.-8 Sep. (10 days), 10-14 Sep. (5 days), 23-27 Sep. (5 days) and, 4-11 Oct. (8 days) coinciding with tillering, flowering, milking and dough stages
2014	1569.3 mm	1235.9 mm to 1338.9 mm	Dryspells from 28-31 June (4 days), 16-19 September (4 days) and 1-11 October (12 days). Scanty rainfall from 22 June to 10 July severely affected germination and seedling growth.
2015	998 mm	490.8 to 637.8 mm	Dryspells from 4-8 July, 12-21 July, 4-7 August, 9-13 August, 2-12 September and no rainfall after 22 September coinciding with the initial growth, tillering, flowering, milking and dough stages of different genotypes
2016	1248.8 mm	959.1 to 967.9mm	Dryspells from 19-27 July, 19 August-1 September, 18 September- 5 October coinciding with the tillering, flowering, milking and dough stages of different genotypes

Planting material

Twenty-six rice genotypes including 22 improved lines from AICRP for Dryland Agriculture, OUAT, Phulbani (ODR lines; ODR denotes 'Odisha dryland rice'), one line from NRRI sub-centre, Hazaribag obtained for evaluation during 2004 (DDR-121), one exotic line from Birsa Agriculture University obtained for evaluation during 1990 (ZHU 11-26) and two lines from NRRI, Cuttack (Vandana and N-22) generally considered as drought tolerant checks, were utilized in the present investigation (Table 2). ZHU 11-26 and DDR-121 were parents of ODR lines. Geetanjali, although a parent, was excluded from this study due to medium maturity duration (130 days). It was used in the hybridization programme for transferring the grain characters (long slender aromatic). Pedigree method of breeding was followed to develop ODR lines.

Experimental plan

The test genotypes were grown under rainfed upland situation during kharif season in the research farm of AICRP for Dryland Agriculture, OUAT, Phulbani for 5 years from 2012 to 2016. The experiment was laid out in randomized block design with three replications. The crop was sown in lines 20 cm apart during last week of June with a fertilizer dose of 60-30-30 kg N-P_2O_5-K_2O. Recommended agronomic practices were followed to raise the crop. A separate experiment was conducted at National Rice research Institute, Cuttack during 2016 to elucidate the reaction of genotypes to drought stress under rainout shelter. Data on early vegetative vigour and drought stress at 33 and 44 days after sowing were recorded (Table 2). Drought stress tolerance was measured in 0-5 scale; 0=very high drought tolerance, 1=high drought tolerance, 3= moderate drought tolerance, and 5=drought susceptible.

Table 2: Characteristics of rice genotypes under study.

S.N	Variety	Source / parentage	Days to 50% flowering	Plant height (cm)	Grain type	Early vegetative vigour	Drought score	
							33 DAS	44 DAS
1	ODR-1-3	Geetanjali × ZHU 11-26	62	87.2	LS	1	1	3
2	ODR-2	Geetanjali × ZHU 11-26	53	65	SS	1	3	3
3	ODR 24 (1)	Geetanjali × ZHU 11-26	65	90.8	SS	1	3	1
4	ODR 1-2	Geetanjali × ZHU 11-26	69	89.9	LS	1	3	1
5	ODR 12-1 (1)	Geetanjali × ZHU 11-26	69	82.2	LS	3	1	1
6	ODR 12-1	Geetanjali × ZHU 11-26	51	79	SS	1	1	1
7	ODR 1	Geetanjali × ZHU 11-26	63	89.7	LS	3	3	3
8	ODR 38	ZHU 11-26 × DDR 121	62	88.2	MS	1	1	3
9	ODR 41	ZHU 11-26 × DDR 121	68	80.3	SS	1	3	3

10	ODR 17	Geetanjali × ZHU 11-26	65	81.2	SS	3	1	1
11	ODR 58	ZHU 11-26 × DDR 121	68	128.1	SS	1	3	1
12	ODR 5	Geetanjali × ZHU 11-26	63	66.7	SS	1	3	3
13	ODR 55 -1	ZHU 11-26 × DDR 121	58	57.2	MS	3	0	0
14	ODR 10	Geetanjali × ZHU 11-26	69	86.5	SS	1	3	3
15	ODR 12C	Geetanjali × ZHU 11-26	66	79.5	SS	3	3	3
16	ODR 12	Geetanjali × ZHU 11-26	58	95.4	LS	3	1	1
17	ODR 1 (1)	Geetanjali × ZHU 11-26	62	89.1	LS	1	3	3
18	ODR 24	Geetanjali × ZHU 11-26	66	91.9	SS	1	3	1
19	ODR 59	ZHU 11-26 × DDR 121	61	95.1	MS	3	1	1
20	ODR 3-14	Geetanjali × ZHU 11-26	53	74.5	SS	3	1	1
21	ODR 12-3	Geetanjali × ZHU 11-26	62	95.8	LS	3	3	3
22	ODR 30	ZHU 11-26 × DDR 121	62	132	SS	1	3	3
23	DDR 121	NRRI (Sub-centre), Hazaribag	63	108.3	MS	3	1	3
24	Vandana	NRRI, Cuttack	65	91.2	SS	3	1	1
25	N- 22	Selection from a local land race at Nagina, U.P.	65	90.1	MS	3	1	1
26	ZHU- 11- 26	An exotic rice variety introduced into Odisha through AICRP Birsa Agricultural University, Ranchi in 1990	58	88.2	MS	3	1	1

Data analysis

The grain yield data over five years was utilized for stability analysis following Finlay Wilkinson model (1963) [4] using PB Tools, version 1.4. 2014 developed by IRRI, Philippines [5]. As per this model, slope of the regression is a measure for adaptability. The average slope equals unity, indicating average adaptability; genotypes with slopes > 1.0 have higher than average adaptability (with greater resistance to environmental changes); and genotypes with slopes < 1.0 have lower than average adaptability.

Results and Discussion

Drought is a serious abiotic stress for rice production and many popular varieties are drought susceptible [6]. Research on quantitative trait loci (QTL) conferring drought tolerance show that QTLs, primarily contributing towards stable yield under drought stress directly or via secondary traits such as root characteristics and leaf rolling, have relatively small effects and different QTLs have been detected in different studies [7,8]. Some QTLs help in significantly increasing water uptake under drought stress and stabilize grain yield [9,10]. Attempts have been taken to identify such useful QTLs in crosses involving popular varieties like Swarna to increase their potential for cultivation in drought-prone environments [11]. Among different genotypes, ODR 12-1 took minimum number of days to 50% flowering closely followed by ODR-2 and ODR-3-14 (Table 2). Three genotypes flowered within 55 days, three between 55-60 days, 13 genotypes between 60-65 days, and rest 7 genotypes between 65-70 days. ODR-1, ODR-1-1, ODR-1-2 and ODR-1-3 had long slender grains with aroma, thus expected to fetch better market price. They took less than 65 days for 50% flowering and possessed high or moderate drought tolerance.

Table 3: Grain yield of new rice genotypes at DLAP (OUAT), Phulbani during kharif, 2012 to 2016.

S.N	Variety	Grain yield q/ha					
		2012	2013	2014	2015	2016	Mean
1.	ODR-1-3	22.37	28.80	21.07	14.99	24.41	22.33
2.	ODR-2	21.03	19.20	14.80	14.99	19.72	17.95
3.	ODR 24 (1)	25.87	33.20	23.93	21.58	23.61	25.64
4.	ODR 1-2	22.95	31.60	18.47	17.61	24.06	22.94
5.	ODR 12-1 (1)	25.17	33.20	22.20	15.96	23.36	23.98
6.	ODR 12-1	23.30	22.08	19.53	15.50	20.47	20.18
7.	ODR 1	24.45	28.08	21.87	18.84	22.66	23.18
8.	ODR 38	20.18	22.56	16.33	15.53	21.60	19.24

9.	ODR 41	25.62	34.00	25.73	24.08	26.69	27.22
10.	ODR 17	17.92	19.80	13.40	13.56	17.40	16.42
11.	ODR 58	20.50	24.80	17.47	11.20	19.32	18.66
12.	ODR 5	18.43	27.60	22.80	13.41	20.07	20.46
13.	ODR 55 -1	23.44	25.40	33.00	21.23	25.85	25.78
14.	ODR 10	16.06	17.92	18.53	13.11	20.53	17.23
15.	ODR 12C	27.68	36.80	32.67	14.99	24.98	27.42
16.	ODR 12	26.52	33.12	24.20	16.91	24.96	25.14
17.	ODR 1 (1)	23.11	29.50	25.33	19.61	23.18	24.15
18.	ODR 24	26.92	33.20	27.20	21.68	25.80	26.96
19.	ODR 59	17.21	16.80	17.60	20.39	18.05	18.01
20	ODR 3-14	15.21	18.00	21.00	12.60	23.00	17.96
21	ODR 12-3	28.53	35.60	29.80	31.51	26.70	30.43
22.	ODR 30	24.10	28.80	21.40	20.90	19.40	22.92
23.	DDR 121	20.58	24.40	20.07	12.36	21.00	19.68
24.	Vandana	22.08	26.90	19.20	21.11	23.72	22.60
25.	N- 22	14.58	14.58	11.51	14.46	17.91	14.61
26.	ZHU- 11- 26	16.88	28.40	17.66	20.90	23.54	21.48
Mean	21.95	26.71	21.41	17.65	22.38		
SE(+m)	0.63	0.86	0.72	0.72	0.67		
CD (0.05)	1.84	2.49	2.09	2.09	1.96		
CV (%)	4.07	4.53	4.73	5.75	4.25		

Table 4: Stability parameters based on Finlay-Wilkinson Model.

S.N	Variety	Slope	SE	t.value	Prob	MSReg	MSDev
1	ODR-1-3	1.538*	0.164	9.337	0.0026	98.27	1.127
2	ODR-2	0.508	0.421	1.206	0.314	10.736	7.377
3	ODR 24 (1)	1.287*	0.31	4.151	0.025	68.765	3.99
4	ODR 1-2	1.613*	0.366	4.411	0.022	107.991	5.55
5	ODR 12-1 (1)	1.902*	0.18	10.551	0.002	150.254	1.35
6	ODR 12-1	0.713	0.343	2.081	0.129	21.121	4.877
7	ODR 1	1.022*	0.158	6.479	0.007	43.347	1.033
8	ODR 38	0.826	0.302	2.736	0.072	28.345	3.788
9	ODR 41	1.115*	0.273	4.088	0.026	51.628	3.089
10	ODR 17	0.732	0.279	2.628	0.078	22.263	3.224
11	ODR 58	1.497*	0.21	7.128	0.006	93.086	1.832
12	ODR 5	1.513*	0.351	4.305	0.023	95.045	5.128
13	ODR 55 -1	0.335	0.77	0.435	0.693	4.653	24.601
14	ODR 10	0.523	0.401	1.304	0.283	11.351	6.672
15	ODR 12C	2.267*	0.709	3.197	0.049	213.435	20.879
16	ODR 12	1.776*	0.163	10.902	0.002	130.929	1.102
17	ODR 1 (1)	1.057*	0.224	4.718	0.018	46.405	2.084

18	ODR 24	1.246*	0.174	7.156	0.006	64.445	1.259
19	ODR 59	-0.379	0.126	-3.015	0.057	5.968	0.657
20	ODR 3-14	0.572	0.678	0.844	0.461	13.605	19.111
21	ODR 12-3	0.45	0.548	0.821	0.472	8.398	12.472
22	ODR 30	0.865	0.436	1.986	0.141	31.097	7.883
23	DDR 121	1.307*	0.248	5.268	0.013	70.888	2.555
24	Vandana	0.702	0.327	2.148	0.121	20.47	4.438
25	N- 22	0.086	0.403	0.215	0.844	0.31	6.738
26	ZHU- 11- 26	0.923	0.651	1. 418	0.251	35.402	17.598

The plant height of different genotypes varied from 57.2 cm in ODR 55-1 to 132 cm in ODR-30. All genotypes had slender grains and were grouped into three categories, such as long slender (LS), medium slender (MS) and short slender (SS). In spite of quite sufficient crop seasonal rainfall in several years, the distribution was erratic with dry spells at critical growth stages that could affect the crop growth and productivity. Significant variation was observed among the test genotypes for grain yield in all the five years (Table 3). Highest mean grain yield was recorded in ODR 12-3 (30.43q/ha) followed by ODR 12C (27.42q/ha) and ODR 41 (27.22q/ha). ODR 12C exhibiting high mean yield along with highest slope (Table 4) can be considered most adaptable. Long slender aromatic genotypes such as ODR 1, ODR 1-1, ODR 1-2 and ODR 1-3 had also high yield coupled with slope >1.0, thus exhibited high stability. Under rainfed upland ecosystem, availability of such high-quality genotypes seems to enhance profitability of rice farming particularly of tribals in hilly tracts. Among these 4 types, ODR 1-2 had high drought tolerance at 44 days after sowing under rain out shelter situation and thus could be advocated for drought prone areas. All other genotypes having comparatively higher grain yield and slope > 1.0 may also be recommended for rainfed uplands.

A crop like rainfed (kharif) rice is more sensitive to rainfall than temperature. In future, water availability is likely to be reduced and soils of high water holding capacity [12] and use of drought tolerant varieties may play an important role in maintaining crop yield. Drought score (DS), performed on the basis of Standard Evaluation System (SES) scale, showed that ODR-55(1) is highly drought tolerant on the basis of leaf rolling and drying character (SES '0'). Since the phenotypic performance of a variety may not be same under different agro-ecological situations due to the influence of environment on genotype, information on phenotypic stability holds a great promise. Stability of a variety enables it to remain unaffected by environmental changes [13]. The aromatic long slender rice genotypes are expected to increase the net income of farmers due to high market price of the produce. Almost 100 volatile compounds have been reported to be responsible for basmati flavor which includes 13 hydrocarbons, 14 organic acids, 13 alcohols, 16 aldehydes, 14 ketones, 8 esters, 5 phenols, etc. [14,15]. The principal compound responsible for aroma, 2-Acetyl-1-pyrroline (2AP), has been detected in the whole above ground plant parts of scented rice [16,17]. In addition to 2AP, several other volatile compounds contributing to the aroma of scented rice cultivars, such as hexanal, nonanal, octanal, decanal, guaicol, indole and vanillin, have been identified [18, 19]. Even in absence of the estimates on aroma, the aromatic long slender genotypes used in the present study with high drought tolerance and stability need attention for rapid spread across locations.

Conclusion

The present investigation highlights the stability of new rice genotypes varying in grain type, aroma, duration and grain yield to justify their suitability for cultivation in rainfed uplands. The genotypes exhibiting 50% flowering within 55 days are expected to escape drought, frequently occurring towards end of monsoon season although they may not possess adequate drought tolerance. The genotypes with high mean grain yield, slope >1.0 and good grain quality like ODR 1-2 are to be adopted for rainfed upland conditions of Odisha in order to improve the economic condition of rice farmers.

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DOI: 10.32474/CIACR.2018.03.000171