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Evaluation of rice (*Oryza sativa* L.) genotypes for direct seeding for the augmentation of its productivity

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Abstract
Direct seeding (DSR) is the process of establishing a rice crop from seeds sown in the field rather than by transplanting seedlings from the nursery and it gaining importance because of its low-input demand. It offers certain advantages *viz*., it saves labour, water, less drudgery, early crop maturity, low production cost, better soil physical conditions for following crops and less methane emission, provides better option to be the best fit in different cropping systems. However, all rice varieties are not suitable for this practice, hence, the study was conducted using 22 high yielding rice varieties to verify their suitability to establish crop through direct seeding. The results revealed the better performance of variety PHB-71 with respect to crop establishment and grain yield followed by KRH-4. Least performance was observed in Raksha both in puddled as well as in aerobic conditions.

Keywords: Rice, direct seeding, genotypes, seedling vigour, crop performance, seed yield

1. Introduction
Rice (*Oryza sativa* L.) is one of the most important food crops grown worldwide for more than half of the world population (Sasaki and Burr, 2000) [7]. Rice belongs to the genus *Oryza* and has two cultivated and 22 wild species. The cultivated species are *Oryza sativa* and *Oryza glaberrima*. *Oryza sativa* is grown all over the world while *Oryza glaberrima* has been cultivated in West Africa for the last ~3500 years (IRRI, 2001). The world's rice demand is projected to increase by 25 *per cent* from 2001 to 2025 with a targeted production of 732.5 MT, which is achievable by addition of 5.9 MT every year (Mahender *et al*., 2015) [8].
Rice is grown under many different conditions and production systems, but submerged in water is the most common method used worldwide. In global rice productivity, 57 *per cent* of rice is grown on irrigated land, 25 *per cent* on rainfed lowland, 10 *per cent* on the uplands, 6 *per cent* in deep water and 2 *per cent* in tidal wetlands (IRRI, 2001). Transplantation of rice seedlings is the most common practice in intensive rice cultivation even after having some drawbacks *viz*., increased labour requirement and exposure of 'transplant shock' that delays rice harvesting for 7-15 days (Khan *et al*., 1992) [7]. The current evidence shows a decline in grain yield productivity due to looming threat to natural resources, waning water table, mounting labour shortage and energy scarcity, increasing input prices and changing climatic conditions (Singh *et al*., 2013) [14].
As the improvement of irrigated condition, implement of efficient herbicide, deployment of new varieties with precocity and high yield and exaltation of labour cost, direct seeding has become an inevitable trend in rice production (Dang *et al*., 2014) [2]. Direct seeding technique aimed at increasing the cropping intensity and reducing transplanting cost, could be employed to boost rice production. It is a method of placing dry seeds into dry soils or soils where moisture is below the field capacity. Direct seeding succeeds based on the topography of land, seedbed condition, oxygen level in the vicinity of germinating seed and method of sowing. Therefore, direct seeding can be classified as (1) wet DSR (sprouted rice seeds are broadcast on wet soil); (2) dry DSR (dry rice seeds are broadcasted or drilled on dry soil) and (3) water DSR (seeds are broadcasted in standing water) (Mahender *et al*., 2015) [8]. Dry and wet seeding methods are popular among the rice farmers of rainfed lowland and gaining its place in irrigated ecology, as they require less labour and time than transplanting (Sarkar and Das, 2003) [11]. Farmers commonly practise wet seeding with pre-germinated seeds, where there is good control over the water supply. In areas where water supply is unpredictable, dry seeding is usually practised (Ella *et al*., 2011 and Gathala *et al*., 2011) [3, 4].

In spite of its clear benefit in many places, the practice of the direct seeding method is insignificant and studies on evaluation of suited varieties for this method are scarce. At the same time, the existing varieties used for lowland culture do not appear to be well-adapted for seedling growth in an initially oxygen depleted micro-environment. By keeping this in view the present study was conducted to screen major high-yielding rice genotypes for their suitability for direct seeding.

2. Material and Methods

Studies were carried out during the *Kharif* season 2016 at Zonal Agricultural Research Station, VC Farm, Mandya, India. Twenty two rice varieties *viz.*, KCP-1, IR-30864, BR-2655, Thanu, Vikas, MTU-1001, Raksha, PHB-71, KRH-4, KRH-2, KMP-153, MAS-946-1, MAS-26, Mandya Sona, Gangavathi Sona, Tunga were seeded directly both in puddled condition and aerobic condition as per package of practice.

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications having a plot size of 2m×5m. Seeds were soaked for 24 hours and excess water was drained out. Sowing of 24hours soaked seed was done in both the condition. All the other agronomic practices were kept optimum in the experiment. Phosphorous and potash was applied as basal dose, where, nitrogen was applied in three equal splits, one third as basal, one third at 30 days after seeding (DAS) and remaining one third at 55 DAS.

Observations were recorded on Field Emergence (%), Canopy height at flowering (cm), Stem length (cm), Leaf blade angle at flowering, Number of panicles/m^2, No. of spikelet's per panicle, Shoot dry weight (g), Seed yield per hill (g), Harvest Index and Seed yield per hectare. Further, evaluated for seed quality parameters *viz.*, 1000 seed weight, Seed germination (%), seedling length and seedling vigour Index. Data recorded and statistically analyzed using Fisher's Analysis of Variance technique and treatment means were compared by Critical Difference at 0.05 probability (Sundarraj *et al*., 1997).

3. Results and Discussion

Twenty two rice genotypes were tested for direct seeding method both in wet (puddled) and dry (aerobic) conditions and all the cultivars showed higher statistical significant difference (Table 1). Varieties vary for crop performance and grain yield among themselves and between methods of cultivation. Field emergence was found to be higher in aerobic condition whereas, it got affected in deep-seeding under puddled conditions. Among 22 genotypes, MAS-946-1 and DRRH-2 showed significantly higher field emergence of 93.0 *per cent* in aerobic condition and least field emergence of 80.0 *per cent* was observed in KRH-4 and Mandya Sona in puddled condition. According to Hoshikawa (1989) [6], with deeper seeding and submerged conditions, seed germination may be delayed; with lack of oxygen because of the standing water, the seedling may not even emerge.

The interaction effect of genotypes and method of cultivation revealed the better crop performance and higher seed yield in puddled condition irrespective of varieties except MAS-26 than aerobic condition. In puddled condition among 22 cultivars, PHB-71 recorded highest number of panicles (1079/m^2), number of spikelets per panicle (273.44), harvest index (0.70) and seed yield per ha. (66.6q). whereas, least seed yield (36.6 q/ha.) performance was observed in var. Raksha under both wet and dry conditions. Gill *et al*., (2006) [5] screened the short duration, early maturing cultivar PR 115 better yield performance than other medium and long-duration varieties in DSR. Sarkar *et al*., (2003) [11] also reported higher grain yield of DSR as compared to PTR mainly because of higher panicle number, higher thousand grain weight and lower sterility percentage. Identification of suitable cultivars for DSR provides adaptability and better water-nutrient uptake under shallow rainfed ecosystem shall help extend the domain of direct seeded rice cultivation to new areas including irrigated areas (Sandhu *et al*., 2019) [10].

In order to ensure lodging resistance hill seeding was done in both puddled and aerobic direct seeding methods. Cultivar PHB-71 noticed to have higher seed yield per hill (443.8g) followed by DRRH-2 (427.23g) and KRH-4 (393.8g) and least was observed in var. Raksha (243.89g) (Table 2). Comparing different seeding methods of direct seeding cultivation, lodging resistance is considered to be highest in hill seeded rice (Yadav *et al.* 2011) [15]. Hill-seeded rice showed remarkable higher pushing resistance than broadcast-seeded rice across a range of seedling density and seeding depth after heading, where the plant length was longer in hill-seeded rice (Yoshinaga, 2005) [16].

Direct seeding method of rice cultivation gain significance because of its higher early seedling vigour, the current study revealed the higher seedling vigour in puddled condition especially in cultivar PHB-71 (443) followed by MAS-26 (436) and lower seedling vigour was noticed in var. Raksha (243). Early seedling vigour (ESV) determines rapid, uniform emergence and the development of seedlings under a wide range of field conditions and it has been considered as one of the important characteristics that determines successful crop establishment (Zhang *et al.*, 2005) [17] under direct seeding rice (DSR).

Table 1: Evaluation of rice genotypes for growth parameters under direct seeding

Sl. No.	Varieties	Field emergence (%)		Canopy height at flowering (cm)		Stem length (cm)		leaf blade angle (at flowering)		No. of panicles per Sq. mt.		No. of spikelets per panicle		Shoot dry weight (g)	
		P	A	P	A	P	A	P	A	P	A	P	A	P	A
1	KCP-1	86	89	86.33	83.69	55.53	52.33	Errect	Errect	902.30	896.67	183.69	171.46	908.8	853.58
2	IR-30864	86	88	87.44	84.20	60.62	57.40	Errect	Errect	953.01	953.33	150.49	138.26	794.11	738.89
3	BR-2655	85	86	103.22	100.72	63.62	60.40	Errect	Errect	955.23	950.00	166.39	154.16	781.27	726.05
4	Thanu	84	86	95.21	91.85	60.22	57.67	Errect	Errect	635.33	630.00	266.83	254.60	774.04	718.82
5	Vikas	83	85	90.33	87.05	70.01	66.50	Errect	Errect	938.56	933.33	146.10	133.87	714.02	658.80
6	MTU-1001	84	86	81.00	77.57	55.62	52.40	Errect	Errect	1055.23	1050.00	127.40	115.17	716.47	661.25
7	Raksha	83	87	82.33	79.06	61.11	57.77	Errect	Errect	851.90	846.67	110.54	98.31	835.19	779.97
8	PHB-71	85	91	82.10	81.02	50.22	47.00	Errect	Errect	1079.00	1077.00	273.44	261.21	977.34	922.12
9	KRH-4	80	84	85.83	82.13	62.35	59.13	Errect	Errect	1038.56	1033.33	145.47	133.24	646.64	591.42
10	KRH-2	80	86	73.11	69.40	58.01	54.77	Errect	Errect	1052.12	1046.67	113.65	101.42	539.83	484.61
11	KMP-153	84	87	84.66	81.39	66.69	63.47	Errect	Errect	921.90	916.67	121.92	109.69	620.59	565.37

12	MAS-946-1	88	93	87.78	87.12	69.40	64.18	Errect	Errect	1055.23	1050.00	200.44	188.21	957.55	902.33
13	MAS-26	83	87	94.90	93.10	57.34	54.12	Errect	Errect	946.22	944.24	213.24	201.01	733.34	678.12
14	Manyda Sona	80	81	94.56	91.30	59.12	55.90	Errect	Errect	811.90	806.67	130.45	118.22	591.65	536.43
15	Gangavathi Sona	83	88	78.70	75.40	57.11	53.73	Errect	Errect	806.21	800.00	173.35	161.12	524.93	469.71
16	Thunga	88	91	107.66	104.4	66.55	63.33	Errect	Errect	881.90	876.67	224.61	212.38	916.06	860.84
17	DRRH-2	89	93	86.44	83.09	58.95	55.73	Errect	Errect	1075.23	1070.00	122.89	110.66	709.43	654.21
18	KMP-175	84	84	86.50	83.25	68.22	65.00	Horizontal	Horizontal	901.90	896.67	194.63	182.4	827.39	772.17
19	BI-33	84	87	94.12	90.87	70.02	66.80	Errect	Errect	1055.23	1050.00	133.27	121.04	728.22	673.00
20	CTH-1	82	85	106.17	102.92	67.95	64.73	Errect	Errect	1068.56	1063.33	138.18	125.95	862.62	807.40
21	Jaya	86	89	83.23	79.98	57.39	54.17	Errect	Errect	858.56	853.33	135.42	123.19	632.81	577.59
22	Rasi	84	87	91.44	88.10	64.56	61.33	Errect	Errect	838.56	833.33	140.30	128.07	646.26	591.04
	Mean	80.8	87.27	89.23	86.26	61.85	55.62			939.98	935.36	164.21	151.98	747.21	691.99
		SEm±	CD@5%	SEm±	CD@5%	SEm±	CD@5%			SEm±	CD@5%	SEm±	CD@5%	SEm±	CD@5%
	V	0.43	1.20	0.946	2.64	1.419	3.96			14.319	39.96	2.58	7.20	23.22	64.8
	M	0.24	0.69	0.528	1.518	0.792	2.27			7.992	22.977	1.44	4.14	12.96	37.26
	VxM	0.86	2.41	1.892	5.302	2.838	7.95			28.638	80.253	5.16	14.46	46.44	130.14

Table 2: Evaluation of rice genotypes for seed yield parameters under direct seeding

Sl. No.	Varieties	1000 seed weight (g)		Seed yield per hill (g)		Harvest Index		Seed Yield (q/ha)	
		Puddeled	Aerobic	Puddeled	Aerobic	Puddeled	Aerobic	Puddeled	Aerobic
1	KCP-1	26.78	25.8	391.22	336.20	0.69	0.57	58.7	50.4
2	IR-30864	27.28	26.3	382.23	346.67	0.70	0.58	57.3	52.0
3	BR-2655	23.48	22.5	365.56	330.00	0.65	0.53	54.8	49.5
4	Thanu	21.18	20.2	359.56	324.00	0.64	0.52	53.9	48.6
5	Vikas	23.88	22.9	321.89	286.33	0.59	0.47	48.3	42.9
6	MTU-1001	25.48	24.5	332.23	296.67	0.63	0.51	49.8	44.5
7	Raksha	24.28	23.3	243.89	208.33	0.42	0.3	36.6	31.2
8	PHB-71	23.98	23.0	443.89	408.33	0.70	0.58	66.6	61.2
9	KRH-4	23.88	22.9	393.89	358.33	0.60	0.48	59.1	59.7
10	KRH-2	20.98	20.0	355.22	345.66	0.60	0.48	53.3	51.8
11	KMP-153	25.38	24.4	280.56	245.00	0.58	0.46	42.1	36.8
12	MAS-946-1	25.99	25.0	427.23	391.67	0.68	0.56	52.1	55.2
13	MAS-26	27.57	26.5	436.68	401.12	0.63	0.51	55.0	58.0
14	Manyda Sona	23.48	22.5	268.89	233.33	0.59	0.47	40.3	35.0
15	Gangavathi Sona	16.98	16.0	262.23	226.67	0.61	0.49	39.3	34.0
16	Thunga	18.58	17.6	344.23	308.67	0.64	0.52	51.6	46.3
17	DRRH-2	25.58	24.6	427.23	391.67	0.62	0.5	64.1	58.8
18	KMP-175	22.38	21.4	385.56	350.00	0.65	0.53	57.9	57.9
19	BI-33	24.88	23.9	338.89	303.33	0.64	0.52	50.8	45.5
20	CTH-1	25.28	24.3	360.56	325.00	0.69	0.57	54.1	48.8
21	Jaya	28.38	27.4	302.23	266.67	0.68	0.56	54.2	53.5
22	Rasi	23.78	22.8	278.89	243.33	0.52	0.4	48.4	49.4
	Mean	24.07	23.09	350.13	314.86	0.63	0.51	52.20	49.10
		SEm±	CD@5%	SEm±	CD@5%	SEm±	CD@5%	SEm±	CD@5%
	V	0.64	1.80	14.31	39.96	0.09	0.25	1.71	4.78
	M	0.36	1.03	7.99	22.97	0.05	0.14	0.95	2.75
	VxM	1.29	3.61	28.63	80.25	0.18	0.50	3.43	9.61

Table 3: Evaluation of rice genotypes for seed quality parameters under direct seeding

Sl. No.	Varieties	Germination (%)		Seedling length (cm)		Seedling Vigour Index	
		Puddeled	Puddeled	Puddeled	Aerobic	Puddeled	Aerobic
1	KCP-1	93	91	26.78	25.80	391.22	336.2
2	IR-30864	89	87	27.28	26.30	382.23	346.67
3	BR-2655	97	95	23.48	22.50	365.56	330.00
4	Thanu	93	91	21.18	20.20	359.56	324.00
5	Vikas	98	96	23.88	22.90	321.89	286.33
6	MTU-1001	90	91	25.48	24.50	332.23	296.67
7	Raksha	90	88	24.28	23.29	243.89	208.33
8	PHB-71	90	88	23.98	23.00	443.89	408.33
9	KRH-4	97	95	23.88	22.91	393.89	358.33
10	KRH-2	96	94	20.98	20.01	355.22	345.66
11	KMP-153	91	89	25.38	24.42	280.56	245.00
12	MAS-946-1	89	87	25.99	25.11	427.23	391.67
13	MAS-26	91	89	27.57	26.58	436.68	401.12

14	Manyda Sona	89	87	23.48	22.48	268.89	233.33
15	Gangavathi Sona	86	84	16.98	16.20	262.23	226.67
16	Thunga	93	91	18.58	17.61	344.23	308.67
17	DRRH-2	94	92	25.58	24.58	427.23	391.67
18	KMP-175	92	90	22.38	21.40	385.56	350.00
19	BI-33	92	90	24.88	23.91	338.89	303.33
20	CTH-1	89	87	25.28	24.33	360.56	325.00
21	Jaya	93	91	28.38	27.41	302.23	266.67
22	Rasi	90	88	23.78	22.81	278.89	243.33
	Mean	92.28	90.05	24.07	23.09	350.13	314.86
		SEm±	CD@5%	SEm±	CD@5%	SEm±	CD @ 5%
	V	1.76	4.92	0.64	1.80	14.31	39.96
	M	0.98	2.82	0.36	1.03	7.99	22.97
	VxM	3.52	9.88	1.29	3.61	28.63	80.25

4. Conclusion
Among 22 cultivars tested for direct seeding both in puddled and aerobic conditions, varieties vary for crop performance and grain yield among themselves and between methods of cultivation. Seed yield and crop performance was better in puddled condition irrespective of varieties except MAS-26. Among the varieties PHB-71 performed better in direct seeding with respect to crop performance irrespective of conditions and grain yield followed by KRH-4. Least performance was observed in Raksha both in puddled and aerobic conditions. Other suitable genotypes identified *viz*., KRH-4, DRRH-2, KCP-1 and KMP-175 also exhibited high values for most of the characters in both the methods of screening. These genotypes need to be analyzed further for innate study of their physiological mechanisms for their tolerance to anaerobic conditions under direct seeded cultivation towards development of diverse cultivars tolerant to puddled conditions.

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