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Varietal Improvement and Weed Management for Aerobic Rice Cultivation in the Drought-Prone Jharkhand State

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Abstract

Aerobic rice varietal and weed management trials under direct seeding were carried out at Birsa Agricultural University Rice Experimental Area, Kanke, Ranchi in the wet seasons of 2017 and 2018. Efforts were made to select better high-yielding varieties and improved production technology for aerobic rice cultivation. Dhaincha (*Sesbania aculeata*), Cowpea (*Vigna unguiculata*), and urd bean (*Vigna mungo*) were grown along with direct seeded rice, uprooted and used as a green mulch, 25 days after seeding. Six varietal trials were conducted under aerobic conditions during the 2017 and 2018 wet seasons in which the entries RP 6191-HHZ1-Y4-Y1-Y1 (6.90 t ha^{-1}), PA 6129 (hybrid) (6.45 t ha^{-1}), RP 6273-HHZ4-DT3LI1-LI1 (6.10 t ha^{-1}), CR Dhan 201 (5.185 t ha^{-1}), US 380(hybrid) (5.28 t ha^{-1}), NVSR 2107 (4.73 t ha^{-1}), IIRRH 124 (hybrid) (4.70 t ha^{-1}) with early maturity were found promising. In varietal trials, intermediate plant height (100 to 110 cm), non-lodging and high yield (>4.0 t ha^{-1}) were major criteria for selection. Two to three irrigations were applied as per the requirement. Naveen variety under aerobic conditions produced maximum yield with 125 kg N per hectare in both years. Among weed control methods, rice+ dhaincha+ pre-emergence application of pendimethalin @ 0.75 g a.i. per hectare in 2017 and rice+ dhaincha+2,4 D @ 0.8 kg a. i. per hectare as post-emergence application produced maximum yield with weed control efficiency of 61.4% in 2018.

Keywords: Aerobic rice, Variety, Weed control, Plant height, Pre-emergence, Post-emergence

Introduction

Rice (*Oryza Sativa* L.) is one of the major staple crops of Asian countries. Two-third of Asian population are dependent on rice for daily calories (Rahman and Masood, 2012). Rice contributed 40 % to the total food grain production in India thereby occupying a pivotal role in food and livelihood security of the people. In terms of area, rice crop grown in about 43 million hectares (mha) in the country, which is the largest acreage in the world. The last sixty years have seen a paradigm shift from subsistence agriculture to technology driven intensive farming which has taken the country from the days of food deficit to an era of self sufficiency. In Asian countries, rice is grown by manual transplanting of seedlings into puddled soil. Puddling and transplanting operations consume a significantly large quantity of water, which is around 30 % of total rice crop requirement (Chauhan, 2012). The rising concern about water availability for rice production is leading the farmers of many Asian countries to shift from manual transplanting to DSR system.

The Jharkhand state is rich in natural resources and dense forests. The state is full of biodiversity but deficient in self sufficiency of food grains because of meagre irrigation facilities i.e. 12-13% in kharif and around 5-6% in rabi. The majority of the farmers in the state are marginal and sub-marginal (**Table 1**) and the land is deficient in major nutrients due to its acidic nature (**Table 2**). Crop production is closely related to the onset of monsoon hence success or failure is linked with rainwater. Currently, monsoons are a gamble with rice cultivation in Jharkhand due to changes in precipitation patterns, the number of rainy days, and the shrinking monsoon period due to climate change. Jharkhand has a net sown area of around 28.0 lakh hectares which is 35.13% of the total geographical area. The cropping intensity of the state is around 125%. At the time of separation, the state was producing only 23.0 lakh metric tonnes of rice from 15.2 lakh hectare but in the year 2021, 48.0 lakh tonnes was produced from an area of 17.63 lakh hectares.

Table 1. Typology land holding in Jharkhand, India

Landholding (ha)	Typology	Percentage (%)
0	Landless	9.3
Up to 0.4	Sub marginal	49.8
0.41-1	Marginal	22.8
1.01-2	Small	12.5
2.01-4	Medium	4.4
>4	Large	1.2
	Total	**100**

Table 2. Soil Profile of Jharkhand

Indicator	Unit (%)	Land typology
Soil with phosphorus deficiency	66.0	Upper, middle and lower portion of toposequence
Acid upland soil	71.0	Upper part of toposequence
pH(<5.5)	49.0	Mainly upper pst of toposequence, forest soils
Soil type :ph(5.5-6.0)	22.0	upper and middle part of toposequence
Red and lateritic (Tanr 2 and 3 and Don 3)	78.0	upper and middle part of toposequence
Alluvium (Don 1 and 2)	19.0	Lower part of toposequence

Jharkhand is a drought-prone state in eastern India. Sometimes, rainfall is adequate throughout the country, but Jharkhand as a whole or in part is always affected by drought. The rice area and productivity are strongly influenced by rainfall patterns and the amount of rain during the wet season. Around 88% of the rice area is rainfed. The state has undulating terrain. Less rain in June-July reduces the rice area, whereas mid–season drought in August and September affects production and productivity. Research on aerobic rice cultivation by direct seeding of fertilizer-responsive high-yielding varieties with supplementary irrigation is a possible option.

Based on the success of direct-seeded rice with sprinkler irrigation in Brazil, and with surface irrigation in China, research on direct-seeded rice with modern varieties, irrigation, and higher fertilizer inputs as compared with rainfed upland, low-yielding direct-seeded rice has been carried out on a small scale since 2006 in Ranchi. Systematic trials in collaboration with the All India Coordinated Rice Improvement Programme (AICRIP) on aerobic rice began in India in 2009. In Brazil, higher yields were obtained with improved plant types under direct-seeded aerobic rice areas using input-responsive drought–tolerant and pest-resistant varieties with sprinkler irrigation or in regions with favourable rainfall distribution (Stone *et al.*, 1990; Guimaraes and Stone, 2000, Pinheiro *et al.*, 2006). In northern China also in water-deficit environments, aerobic rice cultivation has been successful (Wang *et al*., 2002; Yong *et al*., 2005). In India, research has been carried out at the University of Agricultural Sciences (UAS), Bangalore; National Rice Research Institute (NRRI), Cuttack; and Indian Agricultural Research Institute (IARI), New Delhi, for the past 10 years. In the USA, drought screening was part of a strategy to develop aerobic rice cultivars, whereas, at other locations, only varietal evaluation was being carried out.

At BAU, Ranchi, weed management and varietal trials have been conducted. The rice crop is direct-seeded in non-puddled soil like wheat, bunds are made to harvest rainwater, and a higher dose of NPK as with high-yielding varieties (HYV) is being recommended to obtain higher yield. Direct seeding in uplands is common in Jharkhand, but the yield is low because of tall, non-input-responsive varieties. Aerobic rice can be cultivated in the upper, middle, and lower parts of the toposequence, and accordingly, varieties of different maturity duration are needed. Supplementary irrigation is provided through surface irrigation when no rain and moisture stress are visible during any period of crop growth. In direct-seeded rice, weeds are a major problem, so varieties of intermediate height with good seedling vigor are preferred for demonstration. Generally, rains begin in the third week of June and nursery sowing starts for rainfed transplanted crops. In the first fortnight of July, when soils are saturated and rainfall of about 50 mm occurs on a single day, water harvesting through bunds was done and the fields are puddled and transplanted. Growing rice in unpudddled aerobic soil, with the use of external inputs such as supplementary irrigation and fertilizer and aiming for high yield under tropical conditions have also been proposed at IRRI (Bouman *et al.,* 2005). The main driving force behind aerobic rice is economical with water use and timely sowing. As insufficient and delayed rain reduces rice area, and production in transplanted rice cultivation a fundamental approach to reduce water inputs in rice is growing the crop like an irrigated upland crop, such as wheat or maize. Instead of trying to reduce water input in lowland paddy fields, the concept of having the field flooded or saturated is abandoned altogether (Bouman and Tuong, 2001). In direct seeding, weeds are hardy and have a profuse root and shoot growth habit; they grow faster than rice thereby checking the growth of rice plants by severe weed-crop competition. This can be managed by weedicides or with legume crops as mulch.

Materials and Methods

Birsa Agricultural University, Kanke, Ranchi, is situated at 23^0 17' north latitude, $85^0$19' east longitude, and an altitude of 625 m above mean sea level. This location has a subtropical sub-humid climate characterized by hot and dry summer, cold winter, and moderate annual rainfall. The experimental plot represents midland having red loam type of soil, which belongs to the "red, yellow-light gray" group representing the major soil order Alfisols of Jharkhand. The soils are well aggregated with high permeability and low water retention capacity due to the presence of hydrated oxides of iron and aluminum. Soil test values of 100 experimental plots indicated that the soil was sandy loam in texture (Sand 63%, silt 22% and clay 15%), slightly acidic in nature, and moderately fertile, being low in organic carbon, low in available nitrogen, high in available phosphorus, and medium in available potassium.

Two types of experiments were carried out with the Rice Research Unit, Kanke, Ranchi, at BAU during the 2017 and 2018 wet season (WS); One on varietal trials to select higher-yielding, drought-tolerant, disease-resistant varieties; and the other on weed management in aerobic rice.

Varietal evaluation for aerobic rice

Varietal yield trials from AICRIP, Hyderabad, began in 2009 to select better-yielding varieties for midlands. Three yield trials, namely, Initial Varietal Trial (IVT), and two Advance Varietal Trials (AVT-1 &AVT-2), were conducted in the 2017 WS, and three trials in the 2018 WS in Kanke, Ranchi. The IVT was grown in two replications and the AVTs in three replications. The trials were direct seeded in the first week of July with a row-to-row distance of 20 cm and applied 80:60:40 NPK ha^{-1}. A full dose of P and K was applied as basal application while N was applied as top-dressing in two equal splits as urea at 25 and 50 days after seeding. The top dressing was done after hand weeding. Two irrigations were given as and when drought symptoms were visible in the field during the drought spell period.

Weed management in aerobic rice

Weeds are a major problem in direct seeded rice (**Table 3**). A legume crop such as dhaincha (*Sesbania aculeate*), Cowpea (*Vigna unguiculata*), and urd bean (*Vigna mungo*) as green mulch with different nitrogen and weedicide treatments was used in Kanke during 2017 and 2018 wet season with objectives to find the effects of nitrogen rates and weed management on growth, grain yield attributes, grain and straw yield, and weed control efficiency. During 2009 WS, three treatments comprising three nitrogen rates (N_1=75, N_2=100, and N_3=125 kg ha^{-1}) in the main plots and five

Table 3. Major weeds present in the experimental field of rice

Botanical name	English	Family
GRASSES		
Echinochloacolona	Water grass	Poaceae
Digitariasangunalis	Large crab grass	Poaceae
Eleusineindica	Goose grass	Poaceae
Paspalumdistichum	Knot grasss	Poaceae
Brachiariamilliformis	Signal grass	Poaceae
BROAD LEAF WEEDS		
Ludwigiaparviflora	Water purslane	Onagraceae
Sphelenthusacmella	Toothache plant	Spehenocleacae
Eclipta alba	False daisy	Asteraceae
Commelinabenghalensis	Day flower	Commelinaceae
SEDGES		
Cyperusiria	Flat sedge	cyperaceae
Fimbristylismiliaceae	Fimbristylis	cyperaceae
Kyllingabravifolia	Kyllinga	cyperaceae
Cyperusdifformis	Nut sedge	cyperaceae

treatments in the sub-plots (W_1=dhaincha in between rice rows + Pendimethalin at 0.75 kg a.i. ha^{-1}, W_2= rice + Pendimethalin at 0.75 a.i., W_3= Cowpea in between rice rows + Pendimethalin at 0.75 a.i., W_4= weed-free check (two mechanical weedings at 20 and 40 DAS), and W_5= unseeded check). During 2010 WS, sub-plots with seven weed control methods were used: W_1= dhaincha in between rice row + Pendimethalin at 0.75 a.i. ha^{-1}, W_2= rice + Pendimethalin at 0.75 kg a.i., W_3= dhaincha between rice rows + Pendimethalin at 0.75 kg a.i. + 2,4D (0.8 kg a.i.) at 25 DAS, W_4= urd bean rice row + Pendimethalin at 0.75 kg a.i. , W_5= Urd bean in between rice row + Pendimethalin at 0.75 kg a.i. + 2,4D (0.8 kg a.i.) at 25 DAS, W_6= weed free check and W_7= unweeded check. In W_1, W_3 and W_5 treatments, dhaincha, cowpea, or urd bean was uprooted and left in between rows as a green mulch. The experiment was laid out in a split-plot design with three replications. The soil was slightly acidic (pH 6.2), Sandy loam in texture, organic carbon (0.46%) and available nitrogen (228 kg ha^{-1}), high in available phosphorus (35.3 kg ha^{-1}), and medium in available potassium (157.1 kg ha^{-1}). During the 2009 WS, 40 kg P and 20 kg K and in the 2010 WS, 60 kg P and 40 kg K were applied as basal dose in all the treatments. N was applied as DAP (18% N and 46% P_2O_5) as basal dose, and Urea (urea 46% N) as top dressing. P and K were applied through DAP and muriate of potash (60% K_2O). The plot size was 20 cm^2 each.

Results and Discussion

Varietal evaluation for aerobic rice yield trials

2017 yield trials: Three trials, an initial varietal trial aerobic (IVT aerobic), advance varietal trial-1 aerobic (AVT aerobic), and advance varietal trial 2 aerobic (AVT 2 aerobic), were evaluated. The IVT aerobic had 64 entries and was evaluated in two replications. CR Dhan 201 was the national check and Birsa Vikas Dhan 201 was the local check (**Table 4**). Days to 50% flowering varied from 86 to 114 days, Plant height from 80 to 118 cm, and grain yield from 2.30 to 6.90 t ha^{-1}. Late- duration varieties were affected by drought with 55% to 69% grain sterility. Varieties with 110 to 120 cm plant height under direct seeding had better weed competitive ability, and varieties with 115 to 120 days duration were desirable for midland. RP 6191-HHZl-Y4-Y1-Y1 yielded a maximum of 6.90 t ha^{-1} compared with 4.65 t ha^{-1} by CR Dhan 201.

Table 4. Initial Varietal Trial- Aerobic (IVT -Aerob) in 2017 WS at BAU, Kanke, Ranchi

Entries	Yield (t ha^{-1})	Days to 50% flowering	Plant height (cm)	No. of panicle m^{-2}
CR 3721-1-3-1-1-1-2.	2.55	99	105	259
BPT 2601	2.85	114	94	323
RP Bio 4918-B-B-1425	3.15	108	91	365
RP 6273-HHZ4-DT3-L11-L11	6.10	88	105	241
IDP-1-1-1695	2.95	91	102	131
11KR 15-4-1R 99784-255-91-1-5	4.20	87	100	243
TRC-2017-20	4.30	86	96	336
PAU 7554-1-1-1 (EH 214-Y7-Y1-FT-2)	5.40	88	92	274
CR 3721-1-3-1-1-1-2.	4.10	109	114	169
BPT 2601	3.80	91	93	275
RP Bio 4918-B-B-1425	2.55	98	108	253
RP 6273-HHZ4-DT3-L11-L11	2.35	95	103	241
JDP-1-1-1695	3.80	86	100	210
HKR 15-4-1R 99784-255-91-1-5	3.55	91	100	271
CR Dhan 201 (NC)	4.65	90	106	316
RDR-1158	5.35	95	97	335
CR 3996-331-1-2	3.55	88	109	293
Rewa 1113	3.00	92	90	243
US 335 Hybrid	3.85	99	100	323
RP 5934-73-2	3.35	92	99	258
KPH-468 Il,bri	5.65	92	91	226
PAU 6508-273-13-20-6-2	2.30	108	93	290
RP 5594-410-12-6-3	4.15	95	108	211
BPT 2611	2.25	118	98	190
RP 5943-68-17-6-3-1-1-1	4.70	88	128	217
TRC-2017-21	3.70	102	106	333
NWGR-13031	5.40	87	97	220
OR 2567-3	4.80	87	88	305
RP 6222-GSR IRI-12-Y4-D 1 -Y3	5.20	90	100	268
CR 4002-1324-2-2	4.55	95	115	249
PA 6129 (HC)	6.45	90	105	231
CR 4043-1-2-1-1-1-IR95796	3.85	91	102	211
BRR 2085	3.10	91	111	260
HURS 17-9-1R 95836-14-3-1-2	4.75	87	107	232
CR4043-1-2-l-1-l	4.05	90	100	268

Entries	Yield (t ha^{-1})	Days to 50% flowering	Plant height (cm)	No. of panicle m^{-2}
CB 14756	3.95	90	90	297
YRH 2007 (Hybrid)	2.50	99	109	291
CR Dhan 202 (ZC)	4.70	86	96	188
CR 3983-53-1-2-1-2-R95786	5.00	91	82	245
RP Bio 4918-B-B-2215	2.40	109	100	249
RP 6226-GSR IRI-11-YI O-D3-Y3	4.15	90	98	264
HKR 15-3-1R 91326-19-2-1-2	4.25	86	102	188
RP 5933-123-2	3.55	109	99	216
RP Bio 4918 B-B-166SW	2.55	100	114	283
CR 4006-564-3-1-4	3.85	87	97	261
UPR 3976-24-1-1-1	3.85	107	89	271
RP 6275-GSR IRI-15-D4- Dl -YI	4.60	88	80	239
RP Bio 4918 B-B-248L	2.15	107	96	330
UPR3961-6-1-2-1	3.30	107	92	294
R 1700-2247-1-2313-1	3.90	87	98	365
HURS 17-10-IR 93827-27-1-1-2	5.25	88	104	314
CR 3848-1-1-2-1-1	4.00	89	98	301
RP 6112-MS-14-3-9-8-5-4-2	3.40	102	118	288
RCPR 36-1R84899-B-185-8-1-1-2	4.75	86	97	292
RP 5988-78-25-18-5-99-6-70-220	2.65	100	99	288
Rewa 1187	2.75	84	118	254
NVSR -2147	5.00	86	99	241
RP 6191-HHZl-Y4-Y1-Y1	6.90	90	101	242
BRR 2077	3.15	88	102	313
NVSR-2107	5.40	86	101	224
RCPR 25-1R 88964-24-2-1-4	4.00	88	100	334
RP 6263-GSR IRI-5- Y3-Y1-Dl	2.80	100	98	207
CB 14530	3.25	91	102	298
Birsa Dhan 201 (LC)	4.15	99	105	369
CD at 5%	**1.31**			
CV%	**14.66**			

In AVT 1 aerobic, 23 entries were evaluated in three replications (**Table 5**). CR Dhan 201 and Birsa Dhan 201 were used as checks. Grain yield varied from 2.20 to 5.29 t ha^{-1}. The three top-yielding entries were US 380 (5.29 t ha^{-1}), MEPH-134 (5.02 t ha^{-1}), and RP 5601-283-14-4-1 (4.87 t ha^{-1}). CR Dhan 201 out yielded Birsa dhan 201 with 3.29 t ha^{-1}, 3.20 t ha^{-1}, respectively. The plant height of Birsa dhan 201 (112 cm) was also higher and more appropriate than that of CR dhan 201(101 cm).

Table 5. Advance Varietal Trial 1 Aerobic (AVT 1-Aerobic) in 2017 WS at BAU, Kanke, Ranchi

Entries	Yield ($t\ ha^{-1}$)	Days to 50% flowering	Plant height (cm)	No. of panicle m^{-2}
CR 3997-8-IR91648-B-89-B-5-1	2.93	87	98	259
Rewa 1121-475-15-1-1	2.92	87	83	198
OR 2568-4	2.88	81	96	307
BPT 2671	3.38	111	97	206
IR 95812-CR3948-1-2-1-2	3.89	88	103	227
CR Dhan 201 (NC)	3.29	86	101	365
US 380 (hybrid)	5.29	108	101	242
MEPH 134 (hybrid)	5.02	82	98	264
CR 3947-9-25-3-2	3.40	109	98	128
TRC 2015-5	4.00	86	99	168
CB 14932	3.20	74	62	308
AAGP 9412	3.16	79	93	366
CR 3996-11-240-3-1	3.58	86	101	225
RP 5601-283-14-4-1	4.87	90	99	287
RP 5591-123-16-2	3.98	87	95	336
RP 5587-B-B-B-210-1	3.02	86	87	344
CR Dhan 202	3.42	88	101	218
RP 5594-410-53-4-2	2.24	107	102	129
R 1882-306-4-243-1	3.16	89	98	258
RP 5477-N22 SM -162	3.51	112	105	152
PA 6129 (HC)	2.36	86	98	201
RP 5593-83-12-3-1	3.80	88	100	269
Birsa Dhan 201 (LC)	3.04	84	91	457
CD at 5%	**1.08**			
CV%	**12.78**			

In AVT 2 aerobic, 18 entries were evaluated in three replications **(Table 6**). CR Dhan 201 and Birsa Dhan 201were used as checks. Grain yield varied from 3.27 to 6.67 $t\ ha^{-1}$. The entry RP 5955-15-1-1-1-1 gave maximum yield (6.67 $t\ ha^{-1}$) followed by RP 5943-421-16-1-1-B (5.60 $t\ ha^{-1}$). CR Dhan 201 out yielded Birsa dhan 201 yielded 4.33 $t\ ha^{-1}$, 3.20 $t\ ha^{-1}$, respectively.

Table 6. Advance Varietal Trial 2 Aerobic (AVT 2-Aerob) in 2017 WS at BAU, Kanke, Ranchi

Entries	Yield (t ha^{-1})	Days to 50% flowering	Plant height (cm)	No. of panicle m^{-2}
R 1986-296-2-86-1	4.00	88	110	228
PAU-2K 10-23-53-14-52-20-0-4	5.00	100	97	295
PCPR-20-IR83929-B-B-291-2-1-1-2	4.93	82	107	235
TRC-2015-15	4.33	81	103	248
CR Dhan 201 (NC)	4.33	82	103	337
CR 948-2-1-2-2-2-1	3.87	82	102	361
OR 2529-1	3.27	111	98	203
R 1973-206-2-86-1	5.00	83	97	310
UPR 3841-8-1	2.93	89	101	104
CR Dhan 202	5.27	80	104	240
PCPR-21-IR84887-B-158-7-1-1-4	4.80	78	105	234
TRC-2015-12	5.33	86	106	165
CR 3848-1-1-1-6	3.67	82	105	288
PCPR-22-IR848899-B-183-20-1-1-1	4.67	82	115	247
RP 5943-421-16-1-1-B	5.60	84	108	171
OR 2537-1	4.00	107	107	294
RP 5955-15-1-1-1-1	6.67	81	105	246
Birsa Dhan 201(LC)	3.67	76	100	223
CD at 5%	**1.27**			
CV%	**12.54**			

2018 yield trials: In IVT-aerobic, 64 entries were evaluated in two replications (**Table 7**). Two entries namely IIRRH 124 (hybrid; 4.70 t ha^{-1}), and PA 6129 (hybrid; 4.52 t ha^{-1}) yielded maximum. These genotypes were early maturing, duration of 106 days, as compared with other entries of 120 days duration. It was also taller (109 cm) to better compete with weeds.

In AVT-1 aerobic, 16 entries were evaluated in two replications (**Table 8**). CR dhan 201 and Birsa Dhan 201 were the checks. Four entries, *viz.*, NVSR 2107 (4.93 t ha^{-1}), PA 6129 (4.81 t ha^{-1}), HURS 17-10-IR 93827-27-1-1-2 (4.72 t ha^{-1}), and RP 6273-HHZ4-DT3-LI1-LI1 (4.66 t ha^{-1}) were higher yielding than check CR dhan 201 (3.44 t ha^{-1}). The plant height of NVSR 2107 was 87 cm and HURS 17-10-IR 93827-27-1-1-2 was 85 cm. All four selected entries are of medium duration (120 to 131 days).

In AVT-2 aerobic, 17 entries were evaluated in three replications (**Table 9**). Two entries, PA6129 (hybrid; 5.36 t ha^{-1}) and MEPH 134 (5.02 t ha^{-1}) were top yielders. These entries also belong to the medium maturity group, with a plant height of 91 to 101 cm.

All six yield trials during 2017 and 2018 showed wide variability for grain yield, its components, plant height, maturity, and resistance to the natural

Table 7. Initial Varietal Trial- Aerobic (IVT -Aerob) in 2018 WS at BAU, Kanke, Ranchi

Entries	Yield ($t\ ha^{-1}$)	Days to 50% flowering	Plant height (cm)	No. of panicle m^{-2}
OR 25254-1	2.25	103	56	95
Pusa 1827-12-55	2.80	82	73	109
RCPR 57-1R 84898-B-165-9-1 -1	3.15	85	91	163
RP 5977-MS-112-1-9-4-2-35-8-6	3.15	93	109	146
RP6313-GSR IRI-D Q 126-L15-Y1	2.95	85	83	205
R 1532-1101-1-119-1	2.95	88	76	197
RP 5973-20-9-8-24-6-3	2.55	93	69	148
RP 5678-465-544-3	2.45	92	83	189
CR 4160-2-IR 93329:61-B-21-1221-1RGA-2RGA-ı-B-B	3.35	88	85	100
OR 2520-4-1	3.30	85	89	228
IIRRH 124 (Hybrid)	4.65	78	101	195
MSN 101 (DH4)	3.00	81	100	117
TRC 2018-8	3.35	89	86	77
HKR 16-2-IR 9578043-1-1-1	2.80	78	83	104
NVSR 396	2.25	76	87	213
CR 4114-2-1-1-1-1	2.65	88	81	160
US341 (Hybrid)	2.70	92	79	188
CR dhan 201 (C)	2.95	86	70	148
CR 4007-547-1 1-2-1-2-3-3	3.15	83	93	238
NVSR 2285	3.65	86	71	156
NVSR 399	3.05	78	104	160
PAU 5563-23-1-1	2.55	93	84	150
CR 4116-3-2-1-1-1	2.35	100	93	145
NWGR 14071	2.45	92	80	126
YRH716 (Hybrid)	3.10	87	86	143
HURŞ 18-2-11198976-20-1-2-2	3.80	78	80	188
PAU 5563-23-1-1	2.70	82	90	98
CR dhan 202	2.45	91	86	73
CR 4114-1-2-1-2-2-1	3.15	86	92	223
NVSR 391	2.70	86	72	130
HHZ 3-SAL 13-Y2-DT1 (RYT 3578)	2.20	98	83	151
RP 61 12-MS-8-6-5-9-1-3-4-7	3.35	84	82	225
RP 5938-75-6-7-3-1	3.35	92	92	218
CR 4161-4-1R14L 572	2.70	96	70	110
Pusa 1827-12-14	2.85	89	93	173

RP Bio 4918 B-B-166-30	2.00	87	80	71
RP 5401-B-184-2-1-1-1	2.75	84	71	173
RCPR 56-1R 93827-29-1-1-4	2.90	90	86	114
RP 6301-189-17-2	2.70	86	93	263
CR4115-2-1-2-1-1	2.80	84	80	261
CR 3999-377-2-1-2	4.05	79	76	93
PA 6129 (HC)	3.90	75	103	257
CR 4011-8-3-GSRIR1-DQ136-Y8-Y1	3.45	81	73	189
NVSR 395	3.85	90	76	118
YRH721 (HYBRID)	3.30	88	96	161
R 1912-172-2-111-1	3.15	87	72	203
MSN 102	3.00	86	87	107
JGL 24423	2.85	92	77	178
CR 4113-1-1-2-1-1	3.15	85	81	168
NVSR 2112	3.25	85	88	121
CR 4010-8-3- GSR IRI-DQ122Y5-Y1	2.85	97	69	93
JDP 1817 (IR14L594)	2.35	88	81	155
RP 6112-MS494-1 -3-5-2-7-9	3.50	78	80	180
RP 6314-GSR IRI-D	3.10	82	83	193
RP 6307-GSR IR 1-DQ136-Y8-Y1	2.95	84	72	298
CR 4112-2-1-3-2	2.70	85	78	102
TRC 2018-5	2.50	86	90	211
RP 6306-GSR IRI-23-S15-Y1-Y1-D1	3.15	80	84	260
CR 4006-564-3-1-14-3	3.20	73	100	188
RP 5972-13-1-6-67-129-268	3.70	92	92	218
Birsa Dhan 201 (LC)	3.25	96	100	210
CD at 5%	**1.38**			
CV%	**12.56**			

Table 8. Advance Varietal Trial 1 Aerobic (AVT 1-Aerob) in 2018 WS at BAU, Kanke, Ranchi

Entries	Yield (t ha^{-1})	Days to 50% flowering	Plant height (cm)	No. of panicle m^{-2}
CR 3983-53-1-2-1-2-IR95786	3.69	83	326	305
NWGR 13031	2.33	84	273	274
RP 6191-H11Z1-Y4-Y1-Y1	3.11	90	298	285
RP 5977-MS-M42-1-94-2-35-8-6	3.67	92	229	265
TRC 2017-20	3.42	94	236	288
CR Dhan 201 (NC)	3.44	101	208	271
NVSR 2107	4.93	95	325	304
HURS 17-10-IR 93827-27-1-1-2	4.72	90	292	329
CR Dhan 202 (ZC)	3.84	106	234	247

Entries	Yield (t ha^{-1})	Days to 50% flowering	Plant height (cm)	No. of panicle m^{-2}
NVSR 2147	3.38	92	245	274
RCPR25-1R 88964-24-2-14	3.67	91	228	265
PA 6129 (HC)	4.81	88	229	285
CR4043-1-2-1-1-l	2.82	89	316	322
RDR 1158	2.42	89	235	228
RP 6273-HHZ4-DT3-LI1-LI1	4.86	87	229	258
Birsa Dhan 201 (LC)	3.87	88	358	310
CD at 5%	**0.79**			
CV%	**13.56**			

Table 9. Advance Varietal Trial 2 Aerobic (AVT 2-Aerob) in 2018 WS at BAU, Kanke, Ranchi

Entries	Yield (t ha^{-1})	Days to 50% flowering	Plant height (cm)	No. of panicle m^{-2}
OR 2568-4	4.24	81	81	248
TRC2015-5	3.60	87	94	151
RCPR 20-1R83929-B-B-291-2-1-1-2	3.93	86	96	183
RI) 5601-283-14-4-1	3.16	95	88	200
CR Dhan 201 (nc)	3.11	86	92	274
RCPR 22-1R84899-B-183-20-1-1-1	3.82	86	100	169
MEPH 134	4.36	80	99	196
US 380 H,brid)	4.42	95	86	247
CR Dhan 202	3.22	86	92	143
RP 5591-123-16-2	3.31	85	91	238
CR 3996-11-240-3-1	4.18	86	91	227
RP 5943-421-16-I-I-B	3.60	86	105	194
PA 6129 (HC)	4.86	91	88	203
BPT 2671	3.12	97	72	157
R 1882-3064-243-1	3.02	88	86	207
RP 5593-83-12-3-1	3.69	81	95	196
Birsa Dhan 201(LC)	4.09	79	99	285
CD at 5%	**0.69**			
CV%	**12.99**			

infestation of leaf blast and brown spot. Many entries out-yielded the local or national checks, Birsa Dhan 201 and CR Dhan 201. Varieties such as Birsa Dhan 201 were primarily developed for the irrigated ecosystem, and their height decreases in the direct-seeded rainfed ecosystem because of the occurrence of drought spells. There is consistency in the yield superiority of certain entries in both the years. Several varieties have already been released in India, the Philippines, and Nepal (Pradhan *et al.,* 2016). This shows their wide adaptation to the aerobic system of cultivation. These varieties were developed through screening for drought tolerance. This shows that, for developing varieties for aerobic conditions, especially for rainfed environments, drought tolerance is one of the important traits. All other high-yielding varieties should be evaluated in multi-location trials and in farmers' fields through participatory varietal selection. The entries susceptible to blast and the brown spot should be discarded.

Weed Management

Weed management experiments revealed that grain and straw yield were significantly higher at 125 kg N than at 75 and 100 kg N (**Tables 10, 11** and **12**). The increase in grain yield arose mainly from an increase in values for yield components, that is, effective panicles m^{-2}, fertile grains per panicle, and 1000 grain weight. Weed dry matter (g m^{-2}) at harvest

Table 10. Nitrogen x Weed control method (N x W) interaction for grain yield (t ha^{-1}) of aerobic rice variety Naveen during 2017 WS at Kanke, Ranchi

Treatment	N1:75kgN ha^{-1}	N2:100kgN ha^{-1}	N3:125kgN ha^{-1}	Mean
W1: rice+ dhaincha (1:1)+pend. at 0.75 kg a.i.ha^{-1}	3.81	4.23	4.40*	4.15
W2: pend. at 0.75 kg a.i.ha^{-1} + 1 H.W. at 60 DAS	3.41	3.83	3.98	3.74
W3: rice + cowpea (1:1) + pend. at 0.75 kg a.i.ha^{-1}	3.82	4.16	4.27*	4.08
W4: two mechanical weedings (20 and 40 DAS)	3.42	3.79	3.93	3.71
W5: unweeded check	2.84	3.18	3.31	3.11
Mean	**3.46**	**3.84**	**3.98**	
N at same level of W	SEm = 0.15; CD (P=0.05) - NS			
W at same level of N	SEm = 0.17; CD (P=0.05) - NS			

Table 11. Nitrogen x Weed control method (N x W) interaction for weed dry matter (g/m^2) of aerobic rice variety Naveen during 2017 WS at Kanke, Ranchi

Treatment	N1:75kgN ha^{-1}	N2:100kgN ha^{-1}	N3:125kgN ha^{-1}	Mean
W1: rice+dhaincha (1:1)+pend. at 0.75 kg a.i.ha^{-1}	21.6*	23.1	26.5	23.7
W2: pend. at 0.75 kg a.i.ha^{-1} + 1 H.W. at 60 DAS	56.2	72.2	79.7	69.4
W3: rice + cowpea (1:1) + pend. at 0.75 kg a.i.ha^{-1}	26.8	25.2	28.7	26.9
W4: two mechanical weedings (20 and 40 DAS)	54.03	67.5	85.3	69
W5: unweeded check	103.2	108.4	111.2	107.6
Mean	**52.42**	**59.27**	**66.28**	
N at same level of W	SEm= 3.64; CD (P=0.05) = 11.19			

Table 12. Effect of nitrogen doses and weed control methods on grain yield, yield attributes, and weed dry matter of aerobic rice during 2018WS at Kanke, Ranchi

Treatment	Effective panicles m^{-2}	Fertile grains $panicle^{-1}$	1000-grain weight(g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Weed dry matter (gm^{-1}) at harvest*	WCE (%)
Main plot :N level							
N1:75kgN ha^{-1}	234	86.1	23.17	3.53	5.00	26.26 (709.6)	49.2
N2:100kgN ha^{-1}	256	90.5	23.58	3.74	5.52	27.34 (769.6)	44.9
N3:125kgN ha^{-1}	266	95.4	23.72	3.90	5.78	28.86 (850.7)	39.1
CD (P=0.05)	9.6	6.8	0.39	0.11	0.20	0.97	-
Subplot: weed control method							
W1: rice+dhaincha (1:1)+pend. at 0.75 kg a.i.ha^{-1}	284	96.6	24.0	4.30	5.99	24.14 (583.9)	58.2
W2: pend. at 0.75 kg a.i.ha^{-1}+ 1 H.W. at 60 DAS	227	85.2	23.5	3.42	4.96	28.32 (803.7)	42.4
W3: W1+2,4D at 0.8 kg a.i.ha^{-1} at 25 DAS	295	98.1	24.0	4.37	6.17	23.16 (538.9)	61.4
W4: rice + urd bean (1:1) + pend. at 0.75 kg a.i.ha^{-1}	253	90.6	23.1	3.73	5.34	26.82 (721.3)	48.3
W5: W4+2,4D at 0.8 kg a.i.ha^{-1} at 25 DAS	256	91.9	23.5	3.78	5.41	26.2 (689.6)	50.6
W6: weed – free check, H,W at 20 and 40 DAS	257	92.0	23.3	3.94	5.97	26.47(702.9)	49.6
W7: unweeded check	192	80.5	23.2	2.53	4.20	37.31(1396.3)	-
LSD (0.05)	**25.5**	**4.6**	**0.79**	**0.30**	**0.37**	**1.35**	
CV (%)	**9.5**	**5.2**	**4.2**	**8.4**	**7.0**	**5.16**	

was significantly higher at 125 kg N but decreased significantly in treatments with dhaincha, cowpea, and urd bean grown in between rows. The use of pendimethalin at 0.75 kg a.i. in 2017 and 2018 and /or 2,4D at 0.8 kg a.i. ha^{-1} in addition to pendimethalin also reduced weed flora and weed mass. The weed flora in the trial is given in **Table 3**. In the 2017 WS, grain yield biomass was maximum (4.4 t ha^{-1}) in W1 (rice + dhaincha (1:1 interrow) with pendimethalin) (**Table 9**). Weed dry matter was also low in rice+dhaincha or rice+cowpea plots compared with other treatments. Pendimethalin alone with rice was not able to reduce weed biomass (**Table 10**). In the 2018 WS, WCE was maximum 61.4% in W3, the combination of dhaincha in between rice rows + pendimethalin at 0.75 a.i. + 2,4-D at 0.8 kg a.i. ha^{-1}) followed by W1 (dhaincha between rows + pendimethalin at 0.75 kg a.i. ha^{-1}) (Sunil *et al.,* 2018). The use of dhaincha was better than urd bean (**Table 11**). This shows that dhaincha should be preferred, but if it is not available then urd bean that is widely grown as a grain legume crop, can also be used effectively as line mulch or browning through spraying of 2,4-D. Dry matter of weeds at harvest and WCE were higher in interrow crops of dhaincha or urd bean than in mechanically weeded plots.

Conclusion

From the different varietal trials on aerobic rice for two years, it was observed that CR Dhan 201, US 380 (hybrid), and PA 6129 (hybrid) are found to be high yielding than Naveen, selected based on duration and plant type. Naveen was found to be susceptible to leaf blast and brown spot. These varieties can be tested in multi-location trials and in farmers' fields for wide adoption. New high-yielding varieties with tolerance to major diseases and pests must continue to evolve. In weed management trials, the rice variety Naveen grown under aerobic conditions with 125 kg N ha^{-1} was productive and profitable. Planting dhaincha in between rice rows + Pendimethalin at 0.75 a.i. ha^{-1} + 2,4D at 0.8 kg a.i. ha^{-1}at 25 DAS (W_3) suppressed weed density, and weed dry matter accumulation, provided maximum weed control efficiency, and resulted in higher productivity of rice. In the absence of dhaincha seed availability, cowpea and urd bean can also be grown as an intercrop or mixed crop.

Future outlook

The research on aerobic rice in India and drought-prone states such as Jharkhand and others is quite limited. In the era of climate change, and shifts in rainfall patterns, it is essential that systematic research on aerobic rice varietal development and screening for drought tolerance and other location-specific biotic and abiotic stresses should be carried out through multidisciplinary team efforts. Singh and Chinnusamy (2007) have also demonstrated the potential of this technology in farmers' fields of western Uttar Pradesh and the amount of water saved through the adoption of this technology. Globally, Prasad (2011) reviewed the problems, potential, and possibilities in the different countries of the world. In collaboration with IRRI, varietal screening, and agronomic experiments have begun at NRRI, Cuttack and variety Apo was released in 2012 in Odisha. Earlier work at UAS, Bangalore, also lead to the release of Sharada for Karnataka State. If rains are delayed or fail, aerobic rice demonstration through Krishi Vigyan Kendra and on-farm demonstration should be carried out. The extension system of the Department of Agriculture should be involved in the training and dissemination of technology on a large scale.

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