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Evaluation of elite rice genotypes for physiological and yield attributes under aerobic and irrigated conditions in tarai areas of western Himalayan region

Rohit Joshi[a,*,1], Balwant Singh[b], Alok Shukla[a]

[a] Department of Plant Physiology, College of Basic Sciences and Humanities, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, 263 145, India
[b] National Research Centre on Plant Biotechnology, New Delhi, 110012, India

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ABSTRACT

All the irrigated rice systems are currently facing a worldwide challenge for producing higher yield with lower water availability. Aerobic rice is considered to be promising for rice production under water constrained environments where it can be grown under non-flooded and unsaturated soil. All practices for aerobic rice cultivation must start by first identifying promising rice varieties that are expected to produce higher grain yield under such conditions. Therefore, we conducted a field experiment with an experimental design of split-plot in the Tarai region of the Western Himalayas, India, in two irrigation regimes i.e., of continuous flooding and of aerobic condition, using four high-yielding rice genotypes: DRRH-2, PA6444, KRH-2 and Jaya. A grain yield of 743 to 910 g/m^2 was obtained on a typical freely draining soil i.e., under aerobic conditions. Further, DRRH-2 showed enhanced panicle number, spikelet number, filled grain number under aerobic conditions, resulting in the higher grain yield of 910 g m/m^2. We conclude from our studies that the higher productivity of rice depends upon the improved sink capacity (grain number x grain weight) of the genotype, and that this acts as a major factor limiting yield potential under aerobic and flooded conditions.

1. Introduction

Rice is one of the principal food crops of world and accounts for almost 60% of the global energy consumption [1]. Flood-irrigated rice utilizes 45% of the total fresh water, accounting for almost two to three times of that consumed by other cereals [2]. However, by the end of the 21st century, decreasing water resources due to anthropogenic and natural factors will reduce the sustainable production of flood-irrigated rice, a heavy user of water [3,4]. Thus, rice production needs to be increased besides the availability of water, using sustainable water saving technologies and judicious water management practices, in order to feed the increasing global population [4,5,6,7]. Aerobic rice cultivation is an alternative strategy for the conventional methods to deal with water security in the tropical as well as in the sub-tropical agriculture. In the aerobic system, rice is usually directly dry seeded in the non-flooded as well as in the non-puddled fields mimicking the upland conditions, with adequate fertilizer application combined with supplementary irrigation during insufficient rainfall [2,8,9]. This technology utilizes reduced surface runoff, seepage, percolation and evaporation leading to substantial water saving [10].

Lafitte et al. [11] reported that several lowland genotypes survive well in irrigated aerobic soils with occasional flooding. However, under aerobic conditions, even high-yielding lowland rice varieties have shown severe yield loss [12]. Therefore, information using morpho-physiological and yield traits to identify and select superior yield performing aerobic rice genotypes is vital for developing aerobic rice cultivars. However, analysis of correlation between the physiological conditions and the yield of rice showed enhanced grain yield under aerobic conditions [1,13,14,15]. In addition, China Agricultural University (Beijing, China) has developed high- yielding aerobic rice cultivars labelled as “Han Dao” that are being widely grown by the farmers there [16].

In India, 23.3% of the gross cropped area is occupied by rice, which contributes to 43% of the total food grain production and 46% of the total cereal production of India [17]. Moreover, out of the ten million hectares of cultivated rice area in the Indo-Gangetic Basin of India, almost 2.6 million hectares receive either temporal or erratic rains, and are affected by insufficient or irregular surface and ground water supplies during the Kharif (i.e., the autumn) season [18]. To meet the increasing food demand under varying climatic conditions, it is essential

* Corresponding author at: Research Scientist, (Stress Physiology and Molecular Biology Laboratory), School of Life Sciences, Jawaharlal Nehru University, New Delhi, 110067, India.
E-mail address: joshirohit6@gmail.com (R. Joshi).
[1] Google Scholar Profile: http://scholar.google.co.in/citations?user=1X4WDRsAAAAJ&hl=en.

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Table 1
Physico-chemical characteristics of experimental soil.

Parameters	Mean value
pH	7.38
Organic C (%)	0.72
Available N (kg/ha)	202.35
Available P (kg/ha)	20.13
Available K (kg/ha)	178.61
Mn (ppm)	2.64
Bulk density (g/cm^3)	1.38
Electrical conductivity (EC)	0.27
Soil color	Dark Grayish Brown/ Dark Grey
Sand %	12.83
Silt %	63.75
Clay %	29.48
Soil texture	Loam/ Silty Clay Loam

to develop new rice cultivars with improved water use efficiency and those that can be grown under the Himalayan ecosystem. Therefore, in our current research, we have estimated the influence of continuous flooding and aerobic conditions that differentially affect the different rice genotypes during their growth and yield in the Indo-Gangetic Basin of India. Further, our research aims to provide quantitative information on the productivity of these high-yielding genotypes under flooded and aerobic situations in order to determine whether sustainable yield can be obtained under aerobic conditions by improving water management practices.

2. Materials and methods

2.1. Experimental design

Field experiment was carried out at the Norman Borlaug Crops Research Center, Pantnagar, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India (29 °N, 79°29′E and 243.8 m m.s.l.) during the *Kharif* season. The soil was silty clay loam with a pH of 7.38, 202.35 kg/ha total N, 20.13 kg/ha P, 178.61 kg/ha K, and 32.5 meq 100 g^{-1} cation exchange capacity (Table 1). Four genotypes DRRH-2 (IR68897 A/DR 714-1-2R), PA6444 (6CO2/6MO5), KRH-2 (IR 58025 A/KMR-3R) and Jaya (T(N)1xT-141) were used for aerobic treatment, and the flooding was taken as the control (Table 2). Weekly weather data on wind speed (Km/h), minimum and maximum relative humidity (%), minimum and maximum temperature (°C), sunshine (hours/day) and rainfall (mm) during the cropping season were obtained from the Department of Agrometeorology of the University (Fig. 1).

Seedlings were raised in dry nursery beds with alternate day irrigation treatment. Transplanting was done after 25 days in 2 × 3 m plots with a total area of 544 m^2. The row-to-row distance was maintained at 20 cm and the plant-to-plant distance at 10 cm during transplanting. Two-meter distance was retained between the aerobic and the flooded fields to avoid water flow by seepage. Fifteen cm high earthern bunds were mounded to avoid runoff loss in flooded plots and runoff gain in aerobic plots [19]. Regular doses of phosphorus (45 kg P ha^{-1} as single super phosphate), potassium (60 kg K ha^{-1} as muriate of potash), and zinc (30 kg Zn ha^{-1} as zinc sulfate) were applied in all the plots. Nitrogen in the form of urea was applied at three developmental stages (50 kg N ha^{-1} after 15 days of transplanting, 25 kg N ha^{-1} at active tillering and 25 kg N ha^{-1} at the panicle initiation stage). Manual weeding was done to keep the plots weed-free and the recommended doses of pesticides were applied for optimum crop protection. Surface flooding was applied for irrigation through channels connected to the sub surface pressurized pipe system lifting ground water.

Table 2
Parental lines and their significant characteristics of the rice varieties tested in the experiment.

Sl. No.	Name of Variety	Parentage	Year of Notification	Duration (days)	Ecosystem	Salient Features	Recommended for cultivation
1.	DRRH1	IR 58025 A × IR 40750	1996	125-130	Irrigated	Grains are long slender, yield: 7.3 t/ha	Andhra Pradesh
2.	KRH2	IR 58025 Ax KMR-3R	1996	125 - 130	Irrigated	Semi tall (110 cm), non-lodging, non-shattering, long bold grains with high amylose (27%), low ASV (2.2).	Tamil Nadu, Pondicherry, Karnataka, U.P., Bihar, West Bengal, Tripura, Orissa, Maharashtra, Rajasthan and Goa
3.	PA6444	6CO2/6MO5	2001	135	Irrigated	Semi tall (100-120 cm), compact and erect, medium slender grains with intermediate amylase.	Uttar Pradesh, Tripura, Orissa, Andhra Pradesh, Karnataka, Maharashtra and Uttarakhand
4.	Jaya (IET-723)	T(N)1 x T-141	1969	130	Irrigated	Semi dwarf (82 cm) long bold and white grains, moderately susceptible to bacterial leaf blight, sheath blight, rice tungro virus, gall midge and resistant to blast, Yield: 5-6 t/ha.	All India