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Aerobic Rice: Smart Technology of Rice Cultivation

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A B S T R A C T

Rice is one of the most important food crops that feed over half of the global population and biggest consumer of fresh water diverted from irrigation. Water scarcity is burning issue of agriculture, outcome of climate change and unpredictable rainfall. It threatens the future of irrigated rice cultivation. Researchers developed new technology called "Aerobic Rice" to cope up with present situation. Rice is grown in well-drained, non-puddled and non-saturated soils. Aerobic rice cultivar has drought tolerance capacity as well as yield potentiality. Aerobic rice can save about 50% of irrigation water in comparison to lowland rice. To overcome increasing water scarcity problem, this is better choice for both present and future.

Introduction

Rice (*Oryza sativa* L.) is one of the most important staple food crops as it helps to sustain two thirds of the world's population (Kahani *et al.*, 2015). Rice cultivation occupies almost one fifth of the total land area covered under cereals. It grows in a wide range of locations and under a variety of climatic conditions, from the wettest areas in the world to the driest deserts. Although rice is grown in 112 countries, spanning an area from 53 degree latitude north to 35 degree south, about 95 % of the crop is grown and consumed in Asia. It is semi-aquatic annual in nature. For producing one kg rice, it requires 3000 to 5000 liters of water, much higher than requirement of wheat and maize. Generally rice fields are kept flooded for long period of time which enhances seepage, percolation, transpiration and evaporation. Rainfed rice occupies around 45 % of global rice area, but it contributes only 25 % to the world production (Pandey *et al.*, 2000).

Water scarcity and rice cultivation

The global water crisis threatens the sustainability of irrigated rice production in all the rice producing countries. According to Tuong and Bouman (2003), 15 million ha irrigated rice areas of Asia may experience "Physical water scarcity" and 22 million ha may face "Economic water scarcity". Due to growing global population and upgrade in the quality of life, approximately 50% more food will be needed by 2030, with double that being needed by 2050 (Banwart, 2011). So to cope up with such situation, ways must be sought to reduce water requirements in rice and increase its productivity. Different strategies are developed for reducing water consumption for rice cultivation, such as saturated soil culture on raised beds (Borrell *et al.,* 1997), alternate wetting and drying (Bouman and Tuong, 2001), system of rice intensification (Stoop *et al.,* 2002) and aerobic rice cultivation (Bouman *et al.,* 2006). Out of these, aerobic rice is considered to be one of the most promising strategies in terms of water-saving (Tuong and Bouman, 2002).

Aerobic rice cultivation

It is a newly developed concept to produce more yields using less water. In this revolutionary approach, rice is cultivated in non-puddled, non-flooded fields like upland crop with adequate inputs and supplementary irrigation when rainfall is insufficient (Bouman *et al.,* 2005). Aerobic rice can be rainfed or irrigated, should be responsive to high inputs and tolerate occasional flooding (Bouman and Tuong, 2001; Maclean *et al.,* 2002). In Asia, "upland rice" is already under cultivation aerobically with minimal inputs but have low yielding capacity due to the adverse environmental conditions (Lafitte *et al.,* 2002). Traditional upland varieties are drought tolerant and tend to lodge under high level of inputs like fertilizer and supplemental irrigation. On the other hand, if high yielding low land cultivar grown under aerobic condition, it show severe yield penalty (Blackwell *et al.,* 1985; Westcott and Vines, 1986; McCauley, 1990) (Fig. 1).

Aerobic rice cultivar is developed by combining drought resistant characteristics of upland cultivar along with high yielding traits of low land cultivar (Atlin *et al.,* 2006). In this system, the field is not flooded anymore, only wetted like farmer does with maize or wheat (Bouman, 2013). This cultivation is most likely to be desirable, when it show drought tolerance particularly during the sensitive reproductive stage (Garrity and O'Toole, 1994; Atlin *et al.,* 2006). Pioneer research works to advance this technology are going on in China (backed by IRRI), Brazil and India (Predeepa, 2012). China Agricultural University developed special aerobic rice varieties like HD 297, HD277, HD502. These varieties are widely under cultivation in water shortage areas of Northern China.

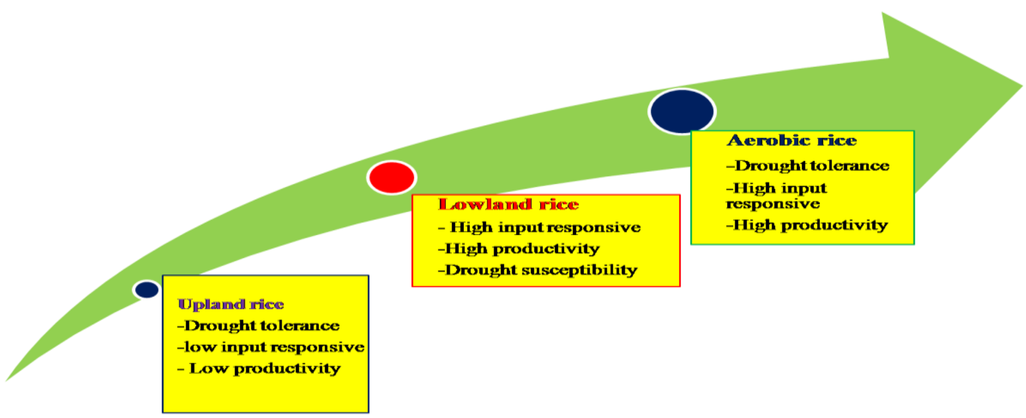
Consequence of aerobic rice cultivation

Rice is single biggest user of fresh water. So a big challenge of lowland rice cultivation is water crisis. Aerobic rice technology provide a viable option for water saving and also maintain productivity. By reducing water use during land preparation, seepage, percolation, and evaporation, aerobic rice had about 51% lower total water use and 32–88% higher water productivity, expressed as gram of grain per kilogram of water, than flooded rice (Bouman *et al.,* 2005). According to Vijayakumar *et al.,* (2006) the water use of aerobic rice was about 60% less than that of flooded rice and total water productivity was 1.6 to 1.9 times higher. The labor use is also saved in aerobic rice because puddling, leveling, raising nursery and transplanting are not required (Wang *et al.,* 2002). Aerobic rice is eco-friendly technique as it emits less methane gas into the atmosphere.

Aerobic rice cultivation in India

India is one of the world's largest producers of rice. In India, rice is grown in the area about 43.39 mha with a production of 104.32 mt and productivity 2404 kg ha^{-1} (Anonymous, 2016). Many parts of India including Haryana and Punjab are facing serious problems due to overexploitation of groundwater. Groundwater tables have dropped on average by 0.5–1.0 m y^{-1} in states of India (Bouman and Tuong 2001). On another side to meet the food needs of ever growing population (1.8%) in India, there is a need to raise rice production to around 130 million tons by 2030 (Viraktamath, 2012). Fortunately India is one of the pioneer countries to adopt aerobic rice technology. Officially India released its first drought tolerant aerobic rice varieties MAS 946-1 in 2007 by University of Agricultural Science, Bangalore. Later it was reported that grain yield of MAS 946-1 under aerobic situation was on par with submerged rice (Gandhi *et al.*, 2012). Several other varieties such as PMK3, MAS25 and MAS26 have also been developed for aerobic cultivation using conventional breeding and marker-assisted selection techniques. CR Dhan 200 and Anagha have been released for cultivation by CRRI, Cuttack (Pradhan *et al.*, 2016).

Fig.1 Evolution of rice cultivation



Hybrid rice under aerobic condition

For success of Aerobic rice technology, specific rice cultivars are required with high yield potential and water deficit tolerance. Outstanding performance of hybrid rice under irrigated condition inspires plant breeders to exploit it under aerobic condition also. Hybrid rice with vigorous and active root system is capable to tolerate moderate water stress. Rajkumar and Ibrahim (2013) identified five hybrids *viz.*, IR 68897 A x MAS – 946 -1, IR 68888 Ax BI 33, IR 58025 A x IR 65912 R, IR 68888 A x MAS 26, TNAU CMS 2A x Vandana suitable for commercial cultivation. Another Four hybrids *viz.*, IR 68885A / IR 73718-3-1-3-3, IR 67684A / CT-6510-24-1-2, IR 70369A / IR 73718-3-1-3-3 and IR 70372A/ PSBRC 80 also showed heterotic vigour for yield and better adaptability under aerobic conditions (Amudha *et al.*, 2010)

Marker Assisted selection in aerobic rice

Breeding of high yielding and drought-tolerant aerobic rice cultivars could be speed up by identification and deployment through marker-assisted breeding of major QTLs that are associated with both yield potential and grain yield under drought stressed aerobic conditions (Venuprasad *et al.*, 2012).

The first QTL (*qtl12.1*) with a large effect on grain yield under stress was detected on Chromosome 12 between SSR markers RM28048 and RM511 (Bernier *et al.*, 2007).

Different large-effect QTLs are identified in the previous studies associated with rice grain yield under drought stress (Bernier *et al.*, 2007; Kumar *et al.*, 2007; Venuprasad *et al.*, 2009), but these QTLs were associated with stress tolerance rather than grain yield under aerobic management per se and either had no effect or had a negative effect on yield potential. Venuprasad *et al.*, (2012) identified qDTY6.1 that is associated with grain yield in a broad range of environments varying in moisture conditions which may used in aerobic rice breeding.

Aerobic-Basmati rice

"Basmati" is long slender-grained aromatic rice which is traditionally from the Indian subcontinent. India is the largest cultivator, consumer and exporter of Basmati rice. Increasing demand of basmati rice and water scarcity motivate scientist for improvement of basmati under aerobic condition. Sandhu *et al.*, (2013) reported two QTLs (qGY8.1 and qGY2.1) and one QTL (qGY2.2) for grain yield under aerobic conditions in the mapping populations MASARB25 x Pusa Basmati 1460 and HKR47 x MAS26, respectively. Rani *et al.*, 2014 identified qGY8.1, qGY2.1 and qRL8.1 for root length in MASARB25 × Pusa Basmati 1460 F_3 mapping population indicating the role of root traits in improving grain yield under water limited conditions.

Aerobic rice is potential technology to give more yields with less water. Low yielding upland varieties can be replaced with aerobic rice cultivar where available water is insufficient for lowland rice. Due to high yield penalty, most of the cultivating varieties are not suitable under aerobic condition. Only few varieties are available for commercial cultivation. For success of this technology, there is need to develop more varieties with maximum water use efficiency and less yield penalty.

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