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Aerobic Rice Development - Prospects, Challenges and Scope

Breeding of rice for low water requirement is a long term goal and it can be achieved with development and cultivation of aerobic rice genotypes. Component traits of aerobic rice needed to be genetically and phenotypically characterized for the successful incorporation. Traits *viz.,* seedling vigour, salinity tolerance, water use efficiency, root exudation, microbiome association, nutrients mobilization and utilization, nutrients use efficiency, higher temperature tolerance, spikelet fertility. These traits should be phenotypically characterized and genomic regions regulating the traits should be identified for successful incorporation to evolve an aerobic rice genotype suitable under tropical upland rice ecosystem with increased productivity levels and less water requirement abilities. Screening methods should be standardized with controlled water application methods, and temperature regulations during critical stages of growth. Magical populations should be evolved by crossing multiple divergent parents to bring the wider genetic pool in one genetic background for the introgression of component traits of aerobic rice genotypes.

INTRODUCTION

Rice is the staple food crop for more than 50% of world population being its sole energy source for tropical and sub-tropical countries. Rice production needs to be doubled globally to meet the food requirements of ever growing world population by 2050. Rice is being grown majorly as a wetland crop with continuous water submergence in which the selection efforts were consciously done for the adaptation. Cultivation of rice and its production always influenced by climatic, biotic and genetic background. Most of the times rice is severely affected by biotic and abiotic stresses causing drastic yield reduction.

Efforts were made to develop high yielding varieties which were adapted to low land conditions with continuous water indentation. Genetic gain through breeding for yield improvement is less than 0.5 % over a period of time. Utilizing rice gene pool for introgressing yield and yield attributing traits are being undertaken i e., climate smart rice, green super rice. Yield of rice has attained a plateau and there are no genetic mechanisms to increase the yield for lowland rice with the existing cultivated germplasm lines.

Lowland cultivation of rice has certainly been disadvantageous due to the following concerns *viz.,* poor nutrient use efficiency, increased methane emissions induced by anaerobic conditions, poor microbiome association in roots, higher water requirements and difficulty in primary tillage and inter cultural operations. Most of the primitive rice cultivars were grown as direct seeded upland crops with no input responses. Genomic changes were gradually happening for thousands of years for forced cultivation of lowland rice to utilise the vast marshy lands of river plains characterized by continuous submergence and only grassy weeds were adapted to inhabit that ecosystem. Hence, direct seeded no input response primitive cultivars were modified to transplanted, manual interventions dependent genotypes of rice suited to low land conditions with continuous water submergence. Water levels were being maintained to keep the crops free from grassy weeds. No input and low input response rice varieties grown in upland and higher altitudes are characterised by long duration photosensitivity and poor yielding. They are part of subsistence farming component practiced by hilly tribes. Dryland rainfed rice of lower altitude plains are short duration types highly tolerant to drought conditions higher temperature and salinity yet poor yielders.

Tropical japan has a unique system of rice cultivation method supported by group of specialized adapted varieties, where rice is cultivated under aerobic conditions with only 50% of total water requirement of paddy. Parameters like soil fertility, temperature, photo period, adaptive cultivars are deciding factors for cultivation of aerobic rice in japan. Yield levels are increased up to 12000 kg/ ha against potential yield of 7700 kg per ha. Two unique japonica rice cultivars *viz.,* Azucena, Moraborakken have been routinely cultivated and utilized in breeding programmes.

AEROBIC RICE - UNDERSTANDING, ISSUES AND CHALLENGES

Aerobic rice is not a mere cultivation method that cannot be performed in all the soils and climatic patterns with any variety of rice. It is cultivation of specially adapted varieties of rice in a particular soil environment *viz.,* high fertility, sandy loam and sub-tropical climate. Nutrient uptake, Nutrient use efficiency, water use efficiency, root morphology, root traits and growth habit are distinctively different from the rice varieties which are adapted to low land conditions subjected to continuous water indentations. Aerobic rice varieties are totally adapted to such environments and can't be cultivated in low land regimes. At the same time, it is impossible to cultivate the low land adapted rice varieties into aerobic rice cultivation. Efforts undertaken by agronomists have become futile due to lack of understanding of adaptations mechanisms of aerobic rice cultivars and low land rice cultivars. Aerobic rice cultivars have distinct early seedling vigour, high input responses, root parameters, water use efficiency, root microbiome association, nutrient use efficiency and sturdy culms with distinct broader leaves with higher levels of lignin content, non-shattering habit, higher photosynthetic rate and high yield potentials. They are direct seeded and perform very well under garden land conditions. But they will not perform well in lowland conditions which are characterized by anaerobic situations. The roots are not well suited for the mobilization of nutrients from lowland conditions. They will exhibit poor growth and development *viz.,* zinc deficiency, stunting and reduced yields. Whereas cultivars which are majorly growing in lowland habitats are adapted to particular microclimate due to continuous water indentations Nutrients availability is based on redox potentials extended by anaerobic situations. Hence, poor nutrient use efficiency, poor water use efficiency, and moderate input responses, subjected to biotic and abiotic stresses sensitivity. Yield is highly influenced by environmental conditions and climatic changes. Zinc deficiency is a peculiar problem of low land rice across the rice growing regions of the country and other countries.

When lowland adapted rice cultivars are forced to cultivate under aerobic method of cultivation, the following issues arise.

1. Poor seedling vigour.
2. Occurrence of zinc and iron deficiency.
3. Poor growth and development.
4. Sensitivity to salinity.
5. Poor uptake mobilization and translocation of nutrients *viz.,* zinc iron phosphorous.
6. Spikelet sterility.
7. Poor dry matter accumulation.
8. Formation of coarse grains which affect the cooking quality.

Indian soils are having mild to severe salinity, due to alternate wetting and drying in sandy loamy soils, anions like carbonates and bicarbonates accumulate in top soil through capillary movements. So they form insoluble complexes with zinc iron and phosphorus which exhibit stunting, poor photosynthetic activity, spikelet sterility. Hence, it is conclusive that to force the high yielding moderate input response low land adapted popular rice varieties under aerobic cultivation methods *viz.,* alternate irrigation followed by wetting and drying, drip irrigation.

Total seasonal water requirement of lowland flooded rice is 1650-3000 mm whereas for aerobic rice is 935 mm. Seepage and percolation loss in lowland flooded rice is 500-1500 mm whereas for aerobic rice is 335mm. Irrigation can be given through flooding up to just enough to bring the soil water content in root zone up to field capacity (FC). The optimum soil water condition would be maintained around field capacity (0.3-04 bar soil moisture potential) across the growth stages. Apply irrigation upon visible symptom of developing hair cracks on surface soil, or initiation of tip rolling of first top leaves. Irrigation, applied at this stage attaining the condition of saturated soil moisture regime. Usually, scheduling irrigation at 5-7 days interval may supplement the optimum water requirement in aerobic rice.

Aerobic rice cultivation has certain distinct advantages over water-logged conventional rice farming including:

1. Saving of 40 - 50% water for irrigation and efficient water management.
2. Less methane production and hence less pollution.
3. Conservation of soil physical, chemical and biological properties.
4. Less chances of mosquito breeding in the stagnant water.
5. Genetic gains for the yields.

However aerobic rice cultivation has not picked up the necessary momentum due to numerous factors *viz.,* thermo sensitivity, salinity, spikelet sterility, inherent soil fertility, lack of efficient root exudation, poor nutrient uptake and mobilization of lowland adapted varieties.

Hence to achieve higher yields through genetic gains is by developing aerobic rice cultivars suitable to tropical climate adapted to wide varying soil environments *viz.,* poor, moderate and high soil fertility.

BREEDING STRATEGIES TO DEVELOP AEROBIC RICE VARIETIES SUITED TO TROPICAL CLIMATIC CONDITIONS

1. Identification of component traits of aerobic rice genotypes *viz.,* early seedling vigour, root exudates, microbiome association in roots, root parameters (length, volume), salinity tolerance, nutrients uptake and utilization, higher temperature tolerance, spikelet fertility, water use efficiency, and higher photo synthetic rates.
2. Simulation models for the performance of hypothetical aerobic rice genotypes with component traits.
3. Designing the screening methods *viz.,* precise discharge of water, temperature regulations, and soil environments.
4. Screening of rice germplasm lines for the component traits under aerobic conditions designed.
5. Identification of potential donors for component traits from different genetic background.
6. Development of magic populations and studying the genetic blocks regulating the component traits by SNP diversity analysis and transcriptomic analysis.
7. Identification of precise aerobic adaptations mechanisms by molecular, transcriptomic and metabolomic studies in roots and developing grains.
8. Designing multiple parents cross combinations for bringing the wider range of component traits into one preferable genetic background.
9. Evaluation of aerobic rice cultivation of genetically introgressed lines under aerobic conditions and

identification of potential aerobic rice variety for adaptations.

10. Conducting multi location trials, adaptive trials and on farm trials for validation and performances.

CONCLUSION

Nevertheless, it is still a hypothetical understanding of aerobic rice genotypes evolution, but with the advancements in structural, functional genomics and metabolomics, it is easy to predict the performance by simulation models. Hence, it is a long way to achieve the development of aerobic rice genotype through concerted breeding efforts by collaborating with soil microbiologist, soil scientist, soil and water conservations engineers, rice physiologist and biochemist.

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