AERobic RICE: A REVIEW

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ABSTRACT

Rice is the staple food in Asia but also the single biggest “user” of fresh water. The declining availability of water threatens the traditional way of irrigated rice production. An efficient use of water is essential to safeguard food security in Asia. Technologies like saturated soil culture and alternate wetting and drying are found promising but require prolonged periods of flooding. Aerobic rice, reduce water inputs in rice field by cutting down the unproductive water losses caused due to seepage and percolation. Experiments on aerobic rice have shown that water inputs were more than 50 per cent lesser (only 470-650 mm) and water productivities were 64-88 per cent higher than the lowland rice, but require improved varieties bred specifically for aerobic condition. Special aerobic rice varieties called “Han Dao” (Such as HD 297, HD277, and HD502) have been developed by the China Agricultural University and are widely grown by farmers. In tropical Asia, IRRI has recently iniated its work on tropical aerobic rice systems and identified that a lowland variety “Magat” and some upland genotypes like “APO” and “CT 6510-24-1-2” perform well under aerobic conditions.

Key words: Aerobic rice, Fresh water.

A Chinese proverb says, “Most precious things are not jade and pearl but rice grains”. Globally rice is grown over an area of about 149 million ha with an annual production of 600 million tones (Bernier et al., 2008). Over 90 per cent of world’s rice is produced and consumed in Asia. Rice is the most important staple in Asia, where it provides 35–60% of total calorie intake (IRRI 1997). Annual per capita consumption of rice in Asia is 79kg. Food security in Asia is challenged by increasing food demand and threatened by declining water availability. More than 75% of the rice supply comes from 79 million ha of irrigated land. Thus, Asia’s present and future food security depends largely on the irrigated rice production system. However, the water-use efficiency of rice is low, and growing rice requires large amounts of water. In Asia, irrigated agriculture accounts for 90% of total diverted freshwater, and more than 50% of this is used to irrigate rice. Until recently, this amount of water has been taken for granted, but now the global “water crisis” threatens the sustainability of irrigated rice production. Therefore, researchers are looking for ways and means to decrease water use in rice production and increase the water use efficiency.

Lowland rice and water requirement:
Irrigated lowland rice in Asia is transplanted or direct seeded into puddled lowland fields. Land preparation consists of soaking, ploughing and puddling. Puddling is done mainly to control weeds, increase water retension, reduce soil permeability and ease field leveling and transplanting (De Datta,
1981). Under irrigated conditions, fields are typically flooded with 5-10 cm of water. Because of the process of flooding, water is lost through percolation and seepage to the deeper layers of soil. Also, water is released by evaporation and transpiration by the crop. Of all the outflows of water from a rice field, only transpiration is productive as it leads directly to crop growth and grain formation. So, instead of keeping the rice field continuously flooded with 5-10 cm of standing water, the flood water depth can be decreased by adopting certain water management techniques essential under present day water crisis (Bouman, 2001).

**Water management strategies to reduce water input in rice:** Large reductions in water input can potentially be realized by reducing the unproductive seepage and percolation flows during crop growth and idle periods.

1. **Saturated soil culture:** In saturated soil culture, the soil in the paddy field is kept as close to saturation as possible. This means that a shallow irrigation is given to about 1-2 cm flood water depth a day or so after the disappearance of standing water (Tabbal et al., 2002). However, implementing saturated soil culture requires good water control at the field level and frequent shallow irrigations that are labour intensive (Thompson, 1999).

2. **Alternate wetting and drying:** In alternate wetting and drying, irrigation is applied to about 2-5 cm flood water depth after a certain number of days (say 5-7) after the disappearance of ponded water. Though alternate wetting and drying have been reported to decrease water input, but at the expense of yield. The yield losses were found to vary from 50-70% depending on the number of days between irrigations and soil conditions (Cabangon et al., 2001).

3. **Aerobic rice:** A new development in water saving technology is the concept of “aerobic rice”. Aerobic rice is a new way of cultivating rice that requires less water than lowland rice. It entails the growing of rice in aerobic soil, with the use of external inputs such as supplementary irrigation and fertilizers and aiming at high yields (Wang et al., 2002). Aerobic way of growing rice saves water by eliminating continuous seepage and percolation, reducing evaporation and eliminating wet land preparation (Castaneda et al., 2002).

The target environments for aerobic rice includes irrigated lowland rice areas where,

- Rainfall is insufficient to sustain lowland rice production (estimated to require about 1200-1500 mm) but sufficient for aerobic rice (about 800 mm).
- In pump irrigated areas where water has become so expensive that lowland rice production was abandoned.
- Water is scarce during the first part of the growing season (requiring irrigation) but floods occur in the second part.
- and favourable uplands with access to supplementary irrigation (Bouman, 2001).

**Water saving in aerobic rice:** In aerobic rice systems, fields remain unsaturated throughout the season (Bouman et al., 2004). Irrigation is by surface method (e.g., flush irrigation, furrow irrigation) or by sprinklers and aims at keeping the soil “wet” but not flooded or saturated (Belder et al., 2005).

Bouman et al. (2002) estimated water requirement for aerobic condition by growing two elite aerobic rice genotypes and one popular lowland variety both under flooded and aerobic conditions. The results of their study has shown that under aerobic condition, the combined amount of rainfall and irrigation water from sowing to harvest varied from 470 to 650 mm, compared with 1350 to 1400 mm in lowland rice and water productivities (calculated as grams of grain produced per kg
of water input) were 64-88 per cent higher than the lowland rice indicating that the water input of aerobic rice is more reduced than the yields.

**Aerobic rice cultivars**: A new type of rice varieties is required to achieve high yields under aerobic conditions. According to Bouman and Tuong (2001) aerobic rice, which can be rainfed or irrigated, should be responsive to high inputs and should tolerate flooding. Moreover, it has to combine characteristics of both upland and high yielding lowland varieties.

Evidence for the feasibility of aerobic rice comes from Brazil and Northern China. In Brazil, a breeding programme on improvement of upland rice has resulted in improved aerobic rice varieties with a yield potential of up to 6t/ha. These new varieties possess the characteristics of modern plant types: medium stature and moderate tillering, resistance to lodging and short erect upper leaves. Farmers grow these varieties commercially on an estimated 2,50,000 ha under sprinkler irrigation (Guimaraes and Stone, 2000).

Special aerobic rice varieties called “Han Dao” (Such as HD 297, HD277, HD502) have been developed by the China Agricultural University. The experimental results showed that under aerobic conditions, the aerobic varieties HD 297 and HD 502 out yielded the lowland variety JD 305. With 470 mm water, HD 297 yielded 2.5 t/ha, HD 502 3.0 t/ha and JD 305 1.2 t/ha; with 644 mm water HD 502 and HD 297 yielded 5.3 and 4.7 t/ha respectively while JD 305 yielded 4.2 t/ha (Geng et al., 2001). The water use efficiencies of aerobic varieties under aerobic conditions were 164-188 per cent higher than that of the lowland variety under lowland conditions (Wang and Tang, 2000). These varieties are currently grown on 1,40,000 ha in Northern China, replacing the traditional lowland rice in water shortage areas. The adoption of aerobic rice is facilitated by the availability of efficient herbicides and seed coating technologies which will help to release essential chemicals/nutrients at a point when the seed germinates in the ground. Also the seed coating technique deliver the desired effect of active ingredients at a low dosage level (Yang et al., 2002).

Studies on bottlenecks in yield formation under aerobic condition analysed using Handao varieties in North China have shown, sink size as the major limitation of aerobic rice yield, because in aerobic rice spikelet number m⁻² was too low (20 000-24 000) compared with the lowland rice. So, future research, should focus on effects of water regimes on tiller dynamics to increase yield (Xie et al., 2008).

In tropical Asia, although no effort has been made yet to breed rice varieties for aerobic rice conditions, IRRI has recently initiated its work and identified several cultivars with high yield potential under aerobic management. IRRI started to develop tropical aerobic rice systems in 2001, using existing improved upland and lowland germplasm and found that yield were 5-6t/ha and water savings were 50-60% compared with flooded rice (Castaneda et al., 2002). Using a promising upland new rice variety, APO, dry season yields at the IRRI farm reached a maximum of 5.7t/ha. Though yields were on average 26% lower than under flooded conditions, water inputs were 44% lower and water productivities 35% higher.

George et al. (2002) evaluated Magat (IR 64616H), a lowland semi dwarf hybrid variety along with other lowland and upland entries under aerobic condition and reported that combination of traits expressed by Magat in aerobic soil such as profuse tillering, markedly reduced plant height, large number of panicles and high Harvest Index helped it to record highest yield (5.3 t/ha) than the other entries.
Atlin et al. (2004) tested aerobic rice varieties APO (IR 55423-01) and CT-6510-24-1-2 along with irrigated high yielding varieties and drought tolerant upland varieties under aerobic conditions to know its yield potential and agronomic features. The results have shown that aerobic cultivars, possessed desirable characters like intermediate plant height, high harvest index and out performed upland and irrigated varieties by 100 and 30 per cent, respectively for grain yield.

Zhao et al. (2004) studied cultivar -weed competitiveness in aerobic rice and reported that the strong association observed between early vigor (a visual seedling biomass rating) and yield under both weedy and weed-free conditions, as well as the high negative correlation of the trait with weed biomass, indicates that early vigor can be incorporated as an useful selection criterion in aerobic rice breeding programs.

In India, researchers are currently testing the growing of popular lowland rice varieties under aerobic conditions on raised beds. The results have shown that yields and water use were comparable with those obtained at IRRI and found that important yield reducing factors under aerobic conditions include weeds, micronutrient deficiencies and nematodes (Singh et al., 2004). Misra et al. (2004) screened 2600 improved germplasm lines under aerobic condition and reported that most of the indica / tropical japonica derivatives and drought tolerant introgression lines showed better adaptability. In Tamil Nadu, a field experiment was conducted by James Martin et al. (2007) to identify suitable rice varieties for aerobic rice cultivation. The upland rice variety PMK 3 produced the highest grain yield of 3684kg/ha and it was significantly superior to other rice varieties tested. The combined amount of effective rainfall and irrigation water from sowing to harvest varied from 520 to 650mm, compared with 1200-1300mm in lowland rice.

**Benefits in adopting aerobic rice** : With the application of aerobic rice culture, large areas of the anticipated 37 million ha of water short irrigated lowlands and parts of the 40 million ha of rainfed lowlands and uplands, where seasonal rainfall is 600-800mm in Asia will be rescued from water shortage problems and brought under cultivation. Growing rice in such areas contributes to food security at large. In China, adopting aerobic rice increased water productivity in terms of both grain yield and net economic returns on water use beyond those achieved in lowland rice production. At two sites in northern China farmers realized net economic returns of US$ 400-600/ha in fields where water scarcity prohibited the growing of lowland rice (Wang et al., 2002). The returns on water use were 50-100% higher than those in lowland rice. Moreover, the use of labour was more than 50% lower than in lowland rice because of the absence of puddling and transplanting as well as less frequent irrigation application and possibilities of mechanized sowing and harvesting in aerobic rice (Bouman et al., 2002).

**CONCLUSIONS**

Over the centuries, lowland rice has proven to be a remarkably sustainable system for rice production mostly because of its luxurious water availability. But the present day water crisis threatens the sustainability of lowland rice production and necessitates the adoption of water saving irrigation technologies. Technologies like saturated soil culture and alternate wetting and drying are receiving renewed attention by researchers. These technologies reduce water inputs only at the expense of yield. Aerobic rice is a new concept to decrease water requirements in rice production and is highly suitable for irrigated lowland rice with insufficient rainfall and favourable uplands with access to
Experiments on aerobic rice have shown that water requirement in aerobic rice were more than 50 per cent lower (only 470-650 mm) and water productivities were 64-88 per cent higher than the lowland rice. However aerobic rice requires new type of cultivars bred specifically for aerobic condition. Currently, IRRI has initiated its work on tropical aerobic rice systems and we are expected to have a potential variety for aerobic condition in the near future.

REFERENCES