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Technologies for Water-saving Irrigation in Rice

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Abstract

More than 75% of the rice produced comes from irrigated land. However, the water crisis threatens the sustainability of the irrigated system. The supply of water for irrigation is endangered by declining water quality, declining resource availability, increased competition from other users, and increasing costs. Rice is especially sensitive to declining water availability since it requires more water than any other food crop and it has relatively low water-use efficiency. Through the adoption of water-saving irrigation technologies, rice land will shift away from being continuously anaerobic to being partly or even completely aerobic. This will have major consequences for other aspects of sustainability, such as weed, pest, and disease ecology and nutrient and soil organic matter dynamics.

Keywords: AWD, Aerobic rice, Rice ecosystems, Water conservation.

1. Introduction

Irrigated wet-season rice mostly grows in the subtropical regions of North and Central China, Pakistan, and northwest India. Dry-season irrigated rice is concentrated in South China, southern and eastern India, and the whole of Southeast Asia. Among them, China, India, and Pakistan have 120 million hectares of (supplementary) irrigated farmland upon which they depend for about half their domestic food production. Salinization has already damaged up to 17% of it through mismanagement of irrigation schemes. The Ganges and Indus rivers have virtually no outflow to the sea in the dry season and, in inland India, in the intensively cultivated states of Punjab and Haryana, groundwater tables fall about 70 cm per year. Tuong and Bouman (2002) estimated that a total of 2 million ha of Asia's dry-season rice and 13 million ha of its wet-season rice will experience ***"physical water scarcity"*** by 2025. The increasing scarcity of water means that the costs of its use and resource development are increasing dramatically. Though water use can be optimized at scale levels from the field to the farm, irrigation system, watershed, and entire river basin, a fundamental approach is to look at water use at the field level where water and the rice crop interact. This is also the scale level that concerns rice farmers most. For farmers with no control over the availability or distribution of water beyond their farm boundaries, the crucial question to be asked is "What are the options to cope with the decreasing water supply (or the increasing costs of it) at the farm or field inlets?" To answer this question, we have to look at the flows of water in rice fields and understand where reductions in water use can be achieved without impairing yield.

Water saving techniques for rice culture has long been documented. There are controversial opinions, however, among rice researchers about potential yield loss associated with reducing water use. De Datta (1981) stated that rice grain yield was highly related to the amount of water use. Castillo *et al.* (1992) reported that draining rice fields at either vegetative or reproductive phases caused significant yield loss. The development of water-use efficiency by using less water to obtain greater rice yield was begun in the early 1900's when dams became popular as a water management tool. In the latter part of the 20th century, the "Green Revolution" led humans to rely on irrigation for agriculture.

2. Water Conservation in Rice Culture

In China, as a result of water depletion in parts of the country, the most widely adopted water saving practice is alternative wetting and drying (AWD). The rice field is allowed to dry for a few days between irrigation events, including a mid season drainage in which the field is allowed to dry for 7-15 days at the end of the tillering stage (4-5 weeks after planting). The potential for water savings in irrigated rice culture is substantial (Bouman and Toung, (2001) reported reduced water inputs and increased productivity of rice grown under saturated soil conditions, as compared with traditional flooded rice. Borell *et al.* (1997) reported that saturated soil culture with rice grown on raised beds reduced the amount of water use by approximately 32 percent as compared with conventional methods. Probably, drying the field can reduce toxicity of organic and inorganic toxins that accumulate from the decomposition of organic materials at the beginning of cropping season (Kongchum, 2005). Short aeration periods at the end of the tillering stage and just before flowering improve wetland rice yields only if followed by flooding (Neue, 1993). The growing scarcity and competition for water is occurring worldwide. Therefore, water conservation practices are the most priority task for increasing agricultural production, particularly rice culture. In this research, a strategy and practice was proposed to increase water use efficiently in irrigated rice culture using an alternate flooding and drying water management technique. The advantage of this technique is to reduced water use by keeping field continuously flooded but allowing it to dry intermittently during the growing season. With this water management technique, the potential to produce more rice with less water from irrigated systems would provide opportunities to conserve water resource and improve food security.

2.1 Saturated soil culture (SSC)

In SSC, the soil is kept as close to saturation as possible. This mostly means that a shallow irrigation is given to obtain about 1-cm floodwater depth a day or so after the disappearance of standing water. With SSC, the water inputs decreased by 30- 60% and the yield dropped by 4-9%, with one exceptional value of 30% in the very permeable soil of Guimba-2 in 1991. Because the water inputs decreased more than the yields, the water productivity (calculated as the ratio of yield over total water input) increased by 30-115%. Bouman and Tuong (2001) compiled a database on SSC and AWD from their own IRRI experiments and experiments reported in the literature. Their database contains information from 31 pot and field experiments carried out in north-central India, the Philippines (Luzon), and Japan. In the 34 data points on SSC, water input decreased by 5% to 50% from the continuously flooded check, with an average of 23%. The yields decreased by only 6% on average, so that water productivity increased. Implementing SSC requires good water control at the field level and frequent shallow irrigations that are labor-intensive.

2.2 Alternate wetting and drying (AWD)

Alternate Wetting and Drying (AWD) is a water-saving technology that lowland (paddy) rice farmers can apply to reduce their water use in irrigated fields. In AWD, irrigation water is applied to flood the field a certain number of days after the disappearance of ponded water. Hence, the field is alternately flooded and non-flooded. The number of days of non-flooded soil in AWD between irrigations can vary from 1 day to more than 10 days. Practical way to implement AWD is to monitor the depth of ponded water on the field using a ‘field water tube’. After irrigation, the depth of ponded water will gradually decrease. When the ponded water has dropped to 15 cm below the surface of the soil, irrigation should be applied to re-flood the field with 5 cm of ponded water. From one week before to one week after flowering, ponded water should always be kept at 5 cm depth. After flowering, during grain filling and ripening, the water level can drop again to 15 cm below the surface before reirrigation. AWD can be started a few days after transplanting (or with a 10-cm tall crop in direct seeding). When many weeds are present, AWD can be postponed for 2-3 weeks until weeds have been suppressed by the ponded water. Local fertilizer recommendations as for flooded rice can be used. Apply fertilizer N preferably on the dry soil just before irrigation. The threshold of 15 cm water depth (below the surface) before irrigation is called 'Safe AWD" as this will not cause any yield decline. In Safe AWD, water savings are in the order of 15- 30%. After creating confidence that Safe AWD does not reduce yield, farmers may experiment by lowering the threshold level for irrigation to 20, 25, 30 cm depth, or even deeper.

2.3 Aerobic rice

A fundamental approach to reduce water inputs in rice is to grow the crop like an irrigated upland crop such as wheat or maize. Instead of trying to reduce water inputs in lowland paddy fields, the concept of having the field flooded or saturated is abandoned altogether. Upland crops are grown in nonpuddled aerobic soil without standing water. Irrigation is applied to bring the soil water content in the root zone up to field capacity after it has reached a certain lower threshold (e.g., halfway between field capacity and wilting point). The amount of irrigation water should match evaporation from the soil and transpiration by the crop. Since it is hardly possible to apply irrigation water to the root zone only, some of it is lost by deep percolation and is unavailable for uptake by the crop.

2.4 SRI

In Madagascar, the 'System of Rice Intensification' (SRI) was developed where fields are kept un-flooded and the soil well aerated throughout the entire vegetative growth, while only a little water is kept on the field during the reproductive growth phase. While this may seem extreme, dramatic yield increases have been witnessed in Madagascar and some other countries. SRI prescribes a set of additional practices, including application of large amounts of organic matter, wide plant spacing, and the transplanting of very young seedlings. Yield increase is tentatively attributed to additive effects of water management, fertilization and timing of transplanting and by unexplained interactions.

3. Summery

Water in irrigated rice production has been taken for granted for centuries, but the "looming water crisis" may change the way rice is produced in the future. Watersaving irrigation technologies that were investigated in the early 1970s, such as saturated soil culture and alternate wetting and drying, are receiving renewed attention by researchers. These technologies reduce water inputs, though mostly at the expense of some yield loss. Farmers in Asia that are confronted with scarcity or high costs of water have already started to adopt these technologies. In China, various forms of alternate wetting and drying and reduced floodwater depth have been developed and massively adopted by farmers (Li 2001). Aerobic rice is a new concept to further decrease water requirements in rice production. In the heart of the rice-wheat belt in India (Haryana, the Punjab, and Uttar Pradesh), innovative farmers are pioneering growing rice aerobically under furrow irrigation in raised-bed systems (Ladha *et al* 2000). Changes in the hydrology of rice production will have major consequences for its sustainability and appropriate management practices. Over the centuries, lowland rice has proven to be a remarkably sustainable system, mostly because of its particular anaerobic character. Water-saving irrigation practices shift away from continuous anaerobic conditions to alternate anaerobic-aerobic and continuous aerobic conditions. The shift from anaerobic to aerobic systems will have major consequences for weed, pest, and disease ecology, nutrient and soil organic matter dynamics, and greenhouse gas emissions and carbon sequestration.

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