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Water Consumption and Rice Productivity Under Puddled and Unpuddled Rice

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India has the largest consumption of groundwater with use of 230 km^3 of groundwater every year (TWB 2012). About 88-90% of extracted groundwater is used for irrigation purpose in agricultural fields. In India, 44 mha area is under rice cultivation, covering 20% of total rice production at world level. To meet the demand of growing population, India needs to produce 130 mt rice by 2030. For achieving the target demand, high-yielding varieties, expansion of rice cultivation area and wet tillage are required, but these increase the irrigation water demand. Rice (lowland) is a less water productive crop (0.2-1.2 kg m^{-3}) as compared to wheat (0.8-1.6 kg m^{-3}) and maize (1.6-3.9 kg m^{-3}). However, the two states Punjab and Haryana reports highest land productivity (4 tonnes per hectare) for rice. These two states uses 100% irrigation practices, but the water productivity is relatively low at 0.22-0.60 kg m^{-3}. This is caused by inappropriate use of irrigation water. Major amount of irrigation water in rice is consumed by puddling and flooding which reduces the water productivity.

Puddled Transplanted Rice (PTR)

In this method, the field ploughing is done with standing water of 5-10 cm depth. It breaks up the clods and churns the soil, and results in impermeable soil layer below the surface layer which increases the retention of the water at surface soil.

Unpuddled Transplanted Rice (UPTR)

Here, the field is made ready for transplanting by a single pass strip tillage (or without tillage) followed by inundation of the field. It takes 2 days for making the land soft sufficient for transplanting.

Direct Seeded Rice (DSR)

Direct seeding is a crop establishment system wherein rice seeds are sown directly into the field by a tractor-powered machine. There is no nursery preparation or transplantation involved in this method.

The water consumption in rice is the most important topic at present. Water consumption is the

total amount of water needed for evapotranspiration from planting to harvest for a given crop in a specific climate. Water use in rice crop under puddled rice can be classified into three ways: Through transpiration, evaporation and combination of seepage and percolation respectively at three scales of rice- the plant, the crop and the field respectively. Transpiration is the loss of water from plant leaves while evaporation is loss of water from the soil surface/ponded water and combinely called as evapotranspiration losses. In rice fields, water is often ponded to ensure there is plenty for the crop to take up. Besides evapotranspiration, outflows of water from a field occur through seepage and percolation which are considered under losses of water. The PTR requires 15-25 cm water column for saturation and flooding of soil. On an average, to produce 1 kg of rice, about 2500 liters of water is required to rice field. A part of this amount is used in evapotranspiration, seepage and percolation. There is large variability is large from 800-5000 liters, which is caused by crop management, weather conditions and soil properties.

Farmers are habitual to growing rice on puddled soils. It positively control weeds, facilitates easy transplanting, establishment of rice seedlings, increases water retention in the rice pond through establishment of a plough pan (reduced percolation rate) and improves nutrient availability. However, it has adverse affects on soil as it destroys soil structure by disturbing the soil aggregates and porosity, increases soil compaction, reduces permeability due to the formation of a hard plough pan zone in the subsurface layer. Formation of a hard plough pan in the long-term puddled soil increases bulk density and soil penetration resistance, reduces hydraulic conductivity, macroporosity and proportion of water-stable aggregates of soil.

Nowdays, DSR have been adopted to reduce the water inputs and improving the water productivity as water required for raising the nursery and transplanting the rice is eliminated in rice. However, DSR take more time than TDR, which would require higher water for evapotranspiration process comparatively. It was found that net water saving depends on water saved from longer irrigation interval and additional water required in pursuance to deep drainage losses in DSR as compared to PTR. A few researchers reported that lesser irrigation amount was required in DSR than PTR with or without yield penalty but the yield reduced rapidly when the soil was permitted to dry beyond soil moisture tension of 20 kPa (Yadav *et al* 2010). For increasing the rice productivity, reduction of unproductive losses becomes necessary.

DSR technology has a positive impact on yield and demands less technology, has great potential producing higher yields and net returns. Direct seeding offers certain advantages like saving irrigation water, labour, energy, time, reduces emission of green house gases, better growth of succeeding crops, etc. On the other hand, conventional puddled transplanting system (PTR) uses large quantity of irrigation water puddling which breaks capillary pores, destroys soil aggregates and forms hard pan below the surface layer, results unfavourable conditions for succeeding crop. Direct seeding helps reduce water consumption by about 30% as it eliminates the need for nursery raising, seedling uprooting, puddling, and manual transplanting.

Water use efficiency and water productivity of DSR (Mallareddy *et al*, 2023)

Location	WUE or Water Productivity (WP) or % Water Saving
PAU, Ludhiana, Punjab	In DSR, water productivity ranged from 0.40 to 0.46, compared to 0.29 to 0.39 kg grain m^{-3} irrigation water under transplanted rice. The water productivity under DSR is 17.9-27.5% higher compared to transplanted rice.

Another alternative to PTR or DSR is unpuddled transplanted rice (UPTR) in which rice seedlings can be transplanted in the unpuddled field by preparing the soil with a single-pass shallow tillage, followed by strip tillage, bed formation, and then transplantation of rice seedlings into the softened land or wetted disturbed slot. Rice seedlings can also potentially be transplanted in the softened surface soil using a mechanical rice transplanter or even manually, similar to puddled transplanting. Unpuddled transplanted rice allows minimal or no soil disturbance, reduced tillage costs, saves water through the elimination of that required for the puddling operation, and potentially increases profit and energy efficiency without any yield penalty (Chaki *et al* 2019). He also reported that UPTR resulted more rice productivity compared to PTR (Table 1).

Table 1 There is some data on comparing rice productivity in PTR and UPTR

Treatment	Mean (kg ha^{-1} mm^{-1})
PTR	39.6
UPTR	55.7

Das et al (2020) reported saving of 31-76% of fuel, 25-26% of water and time required for field prepearation and Hossain *et al* (2017) reported more yield (5.47 t ha^{-1}) in unpuddled rice compared to puddeld rice.

Conclusion

We can conclude that for sustaining the ground water table, there is need to adopt water saving method for rice cultivation. DSR or UPTR can become very helpful for saving the water compared to PTR. DSR and UPTR has more water consumption and productivity compared to PTR. However, some scientists also said that DSR does not reduces water used for rice as it will require more number of irrigations compared to PTR and also results more weed infestation. So, I think there is a need to do more experiments with UPTR to compare it with DSR for water consumption and crop productivity.

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