

Alternate wetting and drying

irrigation technology in rice

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The challenge of climate change induced rainfall variability, falling groundwater levels combined with inefficient use of water are threatening the sustainability of traditional irrigated rice production. Alternate wetting and drying (AWD) is an innovative water-saving technology that allows farmers to maintain grain yields, realize positive economic returns from rice cultivation by less use of irrigation water in irrigation commands. This incentive is the key to scaling adoption of AWD water-saving technology, thereby enabling rapid food grain production growth through sustainable intensification to meet future food demand. Therefore, efforts are under way to mainstream the AWD technology through a network project in 367 farmer's fields across 11 districts of Telangana State.

Keywords: Alternate wetting and drying, Greenhouse gas emissions, Irrigation, Rice, Telangana, Water lodging

RICE (*Oryza sativa*) is the most important crop and staple food of the newly formed Telangana state. With the launch of Mission Kakatiya Project for rejuvenation of tanks, and medium and major irrigation projects particularly Kaleshwaram Lift Irrigation Scheme, area under irrigated rice is continuously increasing over the past 5 years and stands at 2.1 million ha today. Rice irrigation alone accounts for two-thirds of the total gross irrigated area in the state. In almost all the public financed surface irrigation projects and private groundwater sources viz., open wells and tube wells, water resource is largely appropriated by rice. Similarly, a significant part of the energy subsidy provided to agriculture in the state i.e., 2.3 million pump sets are also used for irrigating the rice crop. In 2018-19, the state registered a record second highest procurement level for paddy after Punjab, about 7.75 million tonnes worth ₹ 13,675 crore from 1.47 million farmers. Additionally, the government launched an “Arogya Laxmi” programme which involves

spot feeding of ‘one full meal’ for 21.6 lakhs pregnant and 19 lakhs lactating women where 150 g per day rice besides dal, vegetables, oil, egg and milk are provided to address the malnutrition in the state. Nutritionally rice has been shown to provide 688 kcal per capita per day, i.e., ~32% of total calorie intake per day, 24.1% of total dietary protein, and 3.6% of total dietary fat per day in India.

While rice is a strategic commodity for overall economic growth, source of employment and ensuring food and nutritional security in the state, cultivation of this important staple crop using precious and scarce water resource mostly under inundated agro-ecosystem, demands higher water inputs than other cereal crops. Therefore, to ensure sustainable growth in rice production, Telangana needs alternative methods of rice cultivation to produce more rice with less water. Field experiments at Water Technology Centre, PJ Telangana State Agricultural University, Hyderabad, have shown that

Alternate Wetting and Drying (AWD) is one such irrigation practice that markedly reduce water use while maintaining yield in rice production systems.

Why is AWD important for Telangana?

Rice culture in Telangana consumes about two-third of the total irrigation water used in agriculture. However, climate change induced rainfall variability, falling groundwater levels combined with inefficient use of water is threatening the sustainability of traditional irrigated rice production. Recent study by NABARD found that the total annual water use for irrigated rice production in the state is estimated at 10 billion m³ with an average of about 3,333 litres of water needed to produce 1 kg of unhusked paddy under conventional flooded rice production system. Comparable water productivity values for major rice growing states varied from 1,470 to 4,545 litres per kg of paddy. While the per capita water availability in India decreased by 72.3% between 1950 and 2015 and is likely to

decline by 77.8% by 2050. According to World Bank Report (2010), inefficient use of water in rice production is causing a sharp fall in groundwater table at the rate of almost 0.7 to 1.2 m per year. NITI Aayog's 'Composite Water Management Index 2019' pointed out that already 65% area under rice production in India is facing extreme levels of water scarcity. Additionally, virtual water export adds to the problem – export of 12.5 million tonnes of rice alone annually costs India ~31 trillion litres of water. Further, estimates of greenhouse gas emissions (GHG) from rice production vary, but they all agree rice produces roughly four times the GHG emissions per ton of crop as wheat or maize, mostly in the form of methane and nitrous oxide. A grim water scenario in agriculture together with the highly inefficient rice production technologies currently adopted by a majority of farmers in Telangana warrants the exploration of alternative rice production methods, which inherently require less water and are more efficient in water use. AWD provides some opportunities for saving water.

What is AWD irrigation?

The Alternate Wetting and Drying (AWD) is a controlled irrigation strategy to decrease irrigation water use and reduce greenhouse gas (GHG) emissions from rice cultivation while maintaining or improving grain yields. The AWD practice involves intermittent flooding (alternate cycles of saturated and unsaturated conditions) of a rice field, typically to a water depth of around 5 cm, and allowing the field to dry until the water level drops to a certain threshold moisture level i.e., around 10 cm below the soil surface, and then reflooding the field. Even without ponded water, rice roots can access the water in the subsurface soil, which remains saturated. This cycle of intermittent flooding is commenced 10-days after transplanting or with a 10 cm tall plants in direct seeded crop. Initially, at vegetative stage, the field is flooded to 3 cm depth and left to dry out until the ponded water level in

the perforated field water tube reaches 10 cm below the soil surface. Then the field is flooded again to a water depth varying between 3–5 cm depending on the crop developmental stage. This irrigation scheme of periodic alternate flooded and non-flooded drying cycle is repeated during the entire rice crop growing season except for one week before to one week after flowering, wherein 5 cm ponded water depth above soil should be maintained to avoid water stress which could result in potentially severe yield losses. After flowering, during grain filling and ripening stages, the AWD cycle is continued and water level can drop to 10 cm below the surface before reflooding, referred to as 'Safe AWD irrigation'. The Safe AWD irrigation is a soil water depletion level which is manageable and allowable i.e., at which there is still sufficient water in the root zone depth for optimal crop growth. The number of days of drying period without standing water in rice field in AWD irrigation practice before reflooding varies from 1 to 7 days depending on the soil type, rainfall, weather conditions affecting ET_c, soil moisture and rice crop growth stage. The practice of allowing the ponded water level in the field to drop below the soil surface at one or multiple points during rice cultivation is not new. About 40 to 80% of rice farmers in China and Japan practice some form of short intervals of non-flooded conditions. The AWD irrigation

practice of water management in paddy is also widely accepted as the most promising practice for reducing GHG emissions from irrigated rice for its large methane reductions and multiple benefits.

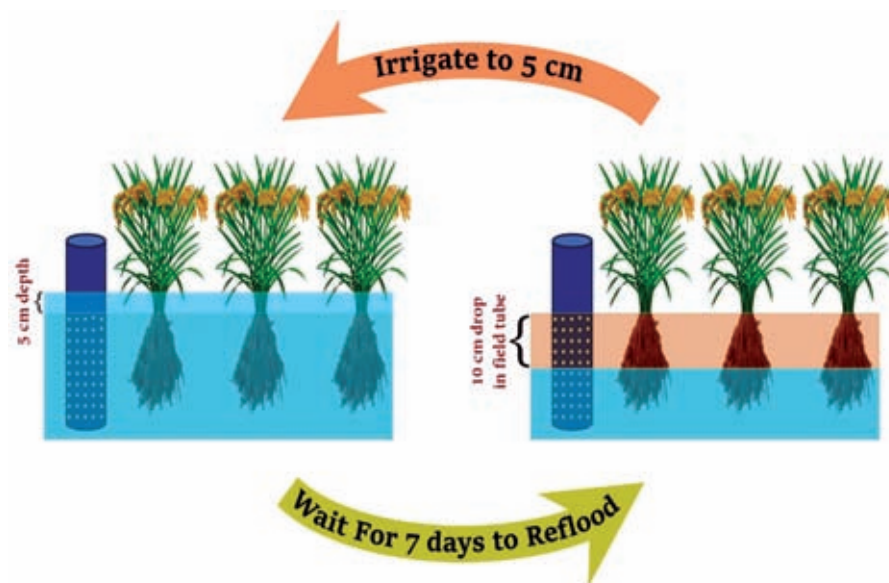
AWD IRRIGATION PRACTICE IN IRRIGATED RICE

How does AWD work in farmers' fields?

Field application of AWD irrigation by farmers is easy to learn by making use of inexpensive plastic water tube to measure water level at any given time in the rice field to know whether it is time to irrigate.

Field water tube for timing irrigation in AWD irrigation

A field water tube is made of 30 cm long PVC pipe having 15 cm diameter so that the water table is easily visible. Drill the bottom 20 cm of field water tube with holes of 5 mm diameter spaced 2 cm apart on all sides. Place the tube in a well levelled readily accessible part of the field for easy monitoring. Bury the drilled side of the tube up till 20 cm depth so that 10 cm of its length remains above the soil surface. Remove the soil inside the tube until the bottom of the tube is visible. Ensure that the level of water inside the tube is the same as the level of water on the field. This field water tube has been effective in assuring farmers that the rice plant is accessing water even when there is no standing water in the field. Once AWD has



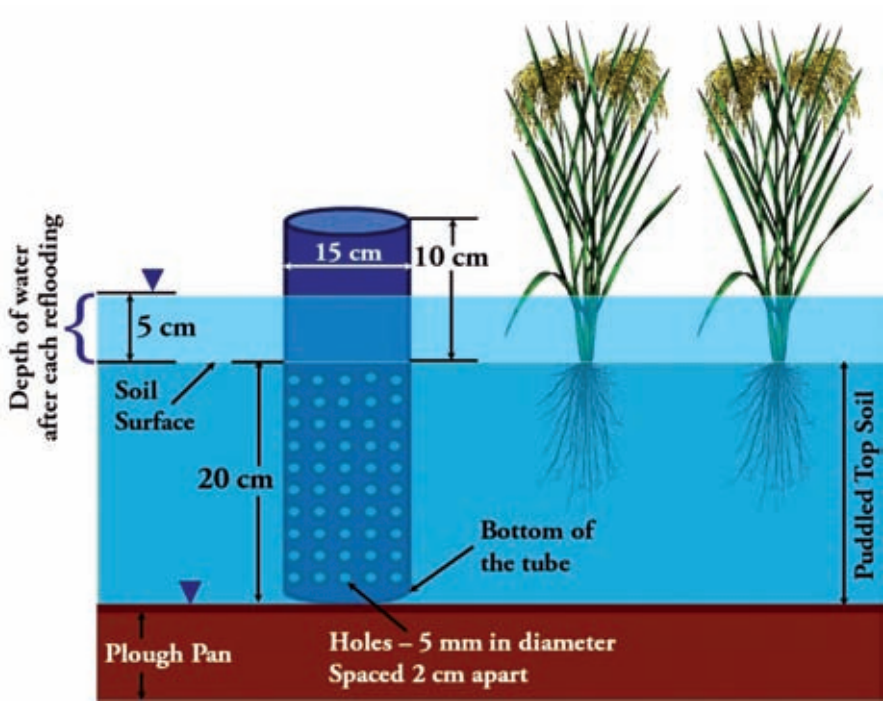
become established, the tube is often dispensed with and farmers base the decision to irrigate on soil monitoring. Proper levelling of rice fields is necessary to ensure that no areas are excessively dry or wet, which could adversely affect grain yields. Laser land-levelling may be appropriate in some farming situations. Weed control is important, as periods of no standing water in rice fields encourage weed growth.

Where AWD can be practiced?

In lowland rice-growing areas where soils can be drained periodically are suitable for AWD. High rainfall may impede adoption of AWD. If rainfall exceeds water lost to evapotranspiration, percolation and seepage, the field will be unable to dry during the rice-growing period. Farmers must have control over irrigation of their fields and know that they will have access to assured and reliable water supplies to reflood once fields have reached the threshold level of safe AWD. Light textured soils and fields with history of blast incidence are not recommended for AWD. Similarly, AWD in rainfed rice and tail-end canal commands is not recommended due to uncertain water availability when fields have to be reflooded.

Benefits for scaling AWD adoption

- **Reduced water application** – Generally rice is cultivated by impounding water in the field to



a depth of 3-5 cm requiring about 16,460 m³/ha of water in Telangana State. On the other hand, intermittent flooding and drying cycle with no continuous standing water during crop growing season in AWD rice fields reduced irrigation requirement while maintaining yields (Table 1). The net irrigation water saving from AWD varied from 26.6 to 35.0%, representing 4,680 to 6,380 m³/ha of water. This was equivalent to a reduction of 500 to 660 litres per kilogram of paddy when compared to continuous flooding. Since, rice

production in Telangana uses around 10 billion m³ of water and almost all of these areas experience water shortages owing to depleting groundwater levels and rainfall variability many farmers do directly benefit from saving water, providing a potential incentive to reduce flooding irrigation in rice. Reduced water consumption using AWD was also shown to reduce upstream-downstream water conflicts and improve social equity in canal commands. Further, these water savings provide a public policy case to implement AWD

Table 1. Impact of AWD on grain yield, water use and economics of rice

Treatment	Grain Yield (kg/ha)	Seasonal water use (m ³ /ha)	Water saving (%)	Net Returns (₹/ha)	Benefit : cost ratio
Continuous flooding – 3 cm up to panicle initiation (PI) and thereafter 5 cm up to physiological maturity (PM)	7568	16460	—	56,378	1.08
Flooding to a water depth of 3 cm from 15 DAT to PM when water level drops to 5 cm below ground level (bgl)	6965	14200	13.73	52,912	1.09
Flooding to a water depth of 3 cm from 15 DAT to PM when water level drops to 10 cm (bgl)	6825	11760	28.56	52,483	0.93
Flooding to a water depth of 3 cm from 15 DAT to PM when water level drops to 15 cm (bgl)	6009	11270	31.53	41,728	1.27
Flooding to a water depth of 5 cm from 15 DAT to PM when water level drops to 5 cm (bgl)	7211	12080	26.61	57,926	1.29
Flooding to a water depth of 5 cm from 15 DAT to PM when water level drops to 10 cm (bgl)	7055	10690	35.05	56,468	1.20
Flooding to a water depth of 5 cm from 15 DAT to PM when water level drops to 15 cm (bgl)	6597	10480	36.33	51,854	1.08
Flooding to a water depth of 3 cm from 15 DAT to PI and thereafter 5 cm up to PM when water level drops to 15 cm (bgl)	6304	10480	36.33	47,058	

irrigation strategy while maintaining yields.

- **Increased net profits for farmers** – Maintaining yields through adoption of safe AWD irrigation practice coupled with lower electricity (pumping water) costs, when power is unsubsidized, increased the net profits on an average by ₹ 4,758 to 6206/ha for AWD farmers. Additionally, mechanization would help to reduce labour costs and further enhance the net profits. These worked as effective incentives for many farmers in Telangana and helped scale AWD adoption.
- **Tolerance to lodging** – Decreased water use also reduced the occurrence of ‘lodging’ (when rice plants keel over due to heavy rain) and helped the crop put forward more effective tillers (the ‘branches’ that eventually carry

grain) and stronger roots. The resulting improved field conditions (soil stability) helped reduced harvesting costs (₹ 500–1,000/ha) and realize positive returns, as mechanical harvesting becomes feasible.

- **GHG mitigation potential** – The growing of rice in flooded fields produces methane because the standing water blocks oxygen from penetrating the soil, creating conditions conducive for methane-producing bacteria. Shorter flooding intervals and more frequent interruptions of flooding in rice fields reduces the emissions of methane—a potent greenhouse gas—by reducing the populations of methane-producing bacteria and stimulating the breakdown of methane by other bacteria. Rice cultivation under flooded conditions is responsible for 10 – 16% of GHG emissions from

agriculture in different countries. Water saving technologies such as AWD irrigation practice reduces the amount of time rice fields are flooded and is reported to reduce the production of methane by about 30 – 50%. Combining AWD with nitrogen-use efficiency and management of organic inputs can further reduce greenhouse gas emissions. AWD could thus become a key component for GHG mitigation in Telangana State.

- Other benefits expressed by farmers in Telangana included early maturity (5–7 days), less incidence of BPH, reduced plant protection costs (₹ 1,000–2,250/acre), no lodging etc.

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Swarna Shakti Dhan: A promising rice genotype identified for aerobic condition

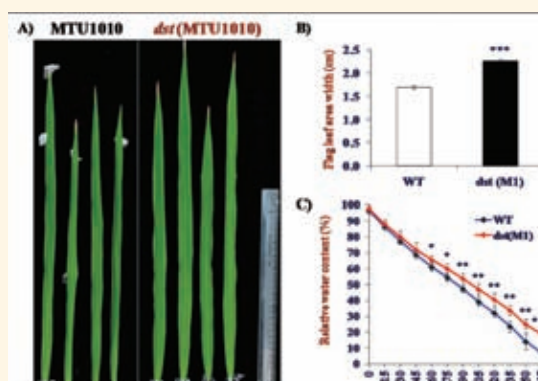
An aerobic rice genotype IET 25640 (RCPR 22) was identified for Zones II (Haryana), III (Odisha, Bihar and Jharkhand), V (Chhattisgarh) and VI (Gujarat and Maharashtra). IET 25640 is an early duration (115–120 days), semi-dwarf, high yielding (4.5–5.0 t/ha), multiple stress (drought, disease and insect pest) tolerant rice genotype with desirable cooking quality traits and high micronutrient (zinc) content. IET 25640 is suitable for cultivation under direct seeded condition in water limiting irrigated areas and rainfed shallow lowland to medium upland ecosystems. This genotype showed desirable quality parameters like high hulling (76.3%), milling (66.36%) and high head rice recovery (63.2%)



Source: DARE-ICAR Annual Report 2019-20.

Genetic improvement of rice for yield, WUE and abiotic stress tolerance

Four genes, viz. *DEP1*, *TB1*, *CKX2* and *SPL4* were selected for genome editing to improve yield by using CRISPR-Cas9 mediated genome editing. Mutant lines for the *Dense erect panicle 1 (dep1)* were developed in rice mega variety MTU1010 and sequence analysis identified various deletion mutations (1–50 bp) in the *DEP1* in different lines. The homozygous T2 *dep1* mutant plants produced semi-dwarf plant phenotype with increased effective tillers and panicles with high grain number. Similarly, genome edited lines for *OsTB1* were generated and confirmed by sequencing. The *TB1* knockout MTU1010 indica rice cultivar produced more productive tillers and enhanced grain productivity. For improving drought and salt tolerance and yield of rice, CRISPR-Cas9 mediated editing of the *DST* (*Drought and Salt Tolerance*) gene was carried out. In T2 generation transgene free genome edited mutant of *DST* gene in indica rice cv. MTU1010 was obtained. This mutant showed broader leaf, lesser number of stomata and lower rate of leaf water loss as compared to the normal MTU1010 cultivar. This mutant will be useful for improving WUE of rice.



Genome-edited *DST* mutant in mega rice cv. MTU1010 background. (A, B) Enhancement of leaf area in *DST* mutant. (C) Reduction of excised leaf water loss in *DST* mutant as compared with WT MTU1010

Source: DARE-ICAR Annual Report 2019-20