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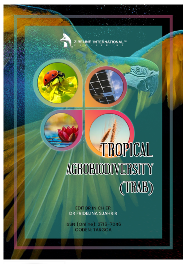

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REVIEW ARTICLE

ALTERNATE WETTING AND DRYING TECHNIQUE AND ITS IMPACTS ON RICE PRODUCTION

Nisha subedi[a*], Samir poudel[b]

[a] College of Natural Resource Management, Puranchaur, Kaski.
[b] Institute of Agriculture and Animal science.
**Corresponding Author Email: neeshasubedi329@gmail.com*

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ABSTRACT

The agriculture sector has been facing challenges due to climate change particularly increasing global water scarcity which threatens irrigated low land rice production. Alternate Wetting and drying (AWD) is a water management system where rice fields are not continuously submerged and the fields are allowed to dry intermittently during the rice-growing period. AWD technique is a necessity for modern farming of rice as it is profitable over the continuous flooding irrigation system which prevents the wastage of scarce and vital water resources, irrigation cost and protects the environment from degradation. It also protects human health from diseases like Malaria as there is an absence of continuous flooding for the mosquito to lay eggs. It helps to enhance food security by increasing the production, nutrient content, and minimizing the toxic elements in rice. However, if this technique is not done properly in the field from time to time, we can also get negative impacts. It varies according to soil condition, irrigation timing, environment, etc.

KEYWORDS

Rice, Alternate Wetting and Drying, lowland

1. INTRODUCTION

Rice is one of the world‟s dominant staple food for more than 3.5 billion people (CGIAR, 2016). It is typically produced in either water-intensive irrigated systems or is dependent on high levels of rainfall (Van Nguyen and Ferrero, 2006). Nearly 75% of global rice production is produced in irrigated lowlands (IRRI,2017). Rice is a heavy water feeder but nowadays water is becoming scarce because of the increasing population and industries (Choudhury et al., 2014). Surface and underground water resources are shrinking which is a limiting factor in rice production (Farooq et al., 2009). Traditional rice cultivation in flooded soils demands a high amount of water than other cereal crops (Pimentel et al., 2004). The amount of water used by the farmers for the preparation of land and during the time of crop growth is much greater than the actual requirement for the field. The traditional water management method results in a high amount of surface runoff, seepage, and percolation which accounts 50–80% of the total water input (Sharma,1989). Asia's water supplies available per capita are projected to decline by 15- 54percent by 2025 as compared to 1990 (Moya et al., 2001). 2500 L of water is required to produce 1 kg of rice (Bouman 2009). Wastage of the resources in the rice field should be minimized as more irrigated land in the world is cultivated with rice (IRRI, 2004).

Approximately 50% of fresh water is being used in irrigation for rice production (Kukal et al., 2004). Global rice production should increase by 70% by 2030 to feed the growing world population (Maclean et al., 2002). The critical stage of water requirement for rice are tillering, panicle initiation, boot leaf stage, heading/panicle emergence and flowering/anthesis (Basha, 2017). Rice growing areas already experience water scarcity problems, so farmers need technologies to cope with water shortage and solutions for these problems must be sought to grow rice with less water (Bouman et al., 2002). Asia‟s farmers depend mostly on monsoon rains. With the prevailing climatic vulnerability, almost half of the planet's population will be living in areas of high-water shortage by 2030 (UNCCD, 2014). Rice production plays a significant role in Nepal's economy. In Nepal, 42.5 percent (168,047 ha) of the total area under food grains is dominated by rice cultivation and shares 51.6 percent in total food grain production (MOAD, 2017).

IRRI develop a precise water management technique called alternate wetting and drying (AWD) to save irrigation water use in the paddy field (Bouman and Tuong 2001). AWD technique first began in China and India in the 1980s and 1990s (Mushtaq et al., 2006). Alternate wetting and drying (AWD) is considered as a water-smart, weather-smart, and carbon-smart technique in rice production (Wassmann et al., 2019). AWD is based on a principle of flooding and non-flooding of fields alternately during the rice-growing period (Richards and sander, 2014). Frequency of irrigation and duration of non-flooding can be determined by re-irrigating the field after a fixed number of non-flooded days, as a certain threshold of soil water potential is reached, water table level drops to a certain level below

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the soil surface, cracks appear on the soil surface or when plants show visual symptoms of water shortage (Peng and Bouman, 2007). AWD tool is a single device designed to observe the water level in the rice field and to decide the time of irrigation.

Perforated pipe (preferably PVC) is installed in the rice field to allow observation of water level. In one part, such a pipe of 10cm diameter and 30cm long is installed having 10cm above and 20cm below the ground surface. A study recorded the successful usage of field water tube in the AWD management regime to monitor the water depth and capable to indicate the right time of irrigation and saved water, without any yield penalty (Tuong, 2007). Commonly, irrigation is applied to obtain 2–5 cm ponded water depth after a certain number of days (ranging from 2 to 7) have passed following the disappearance of ponded water (Rahman, 2014). AWD irrigation was generally administered with 5, 7- and 10-days interval, but the predetermined days of interval could not be treated as the demand-driven approach perfectly (Latif, 2010). AWD is the method of managing the water in which water will not be wasted rather it will aid the root growth, facilitate higher nutrient uptake, and increase land and water productivity (Sarkar, 2001). Many factors play a role in determining the success or failure of AWDI. Some of the factors that can be influenced are irrigation infrastructure and irrigation management capacity, while others cannot be, such as rainfall and soil conditions (Rajendran et al., 1995). Besides water management, all other cultural practices for AWD and continuously flooded rice are the same, including nitrogen management (Cabangon et al., 2011).

2. Impacts of AWD

2.1 Impacts on production

Little water stress to the plant doesn't not decrease the grain yield. The lowest grain yield was obtained from continuous standing water. Applying irrigation water in the rice field when the water level goes 15 to 25cm below ground level does not reduce the total number of filled grains compared to that of 5cm standing water (Rahman, 2014). Standing depth of water throughout the season is not needed for high rice yields. If soil drying in the AWD regime was controlled properly such an AWD could not only save water but also helps to increase grain yield (Zhang et al., 2009). A study reported an increase in paddy yield under AWD due to the increase of the proportion of productive tillers, reduction in the angle of the topmost leaves allowing more light penetration into the canopy, and change in shoot and root activity (Yang and Zhang, 2010). A group researcher reported no significant difference in rice yield between AWD and CF with 57% of irrigation water saving under AWD in Agyauli in the central Terai region of Nepal (Howell et al,2015). The soil oxygen content in rice fields under water- saving irrigation is 120–200 percent of that under-flooding irrigation (Mao Zhi 1993). Higher amounts of carbon were released from roots into the soil under non flooded and AWD regimes than in continuously flooded cultivation leading to higher microbial numbers and biomass in the rhizosphere of rice (Tian et al., 2012).

Conventional method of irrigation practice produced higher grain and straw yields and it was comparable with AWD irrigation regime of 5 and 10 cm drop of the water table (Kannan, 2014). Sufficient oxygen is supplied to the root system to accelerate soil organic matter mineralization and inhibit soil N mobilization which results in increase soil fertility and produces more essential plant-available nutrients to favor rice growth in AWD (Dong et al., 2012). Irrigation to rice two days after the disappearance of the stagnant water at the vegetative phase was found to be the best irrigation practice for getting higher grain yield (Patel, 2000). AWD may result in increased N losses due to nitrification and denitrification, which can lead to reduced plant N uptake (Pandey et al., 2014).

Root growth is essential for water and nutrient uptake, which affects rice grain yield (Wang et al., 2016). Rhizosphere drying alters plant hormone signaling and enhances grain filling rate, particularly in inferior spikelets (Zhang et al., 2010). Tiller number was significantly higher under AWD than CF (Continuously flooding) from 21 days after transplanting onwards. Tiller number was significantly higher in CH- 45 from 21 to 35 days after transplanting, and remained higher thereafter (Howell et al., 2015). AWD significantly decreased yields in some years (possibly due to erratic rainfall) but not in others (Mandal et al. 2009). Higher numbers of tillers and effective tillers under AWD may have caused more competition between tillers and panicles for plant resources, which results in significantly lower grain weight, number and filling (Peng et al., 1994). Lower tiller number under AWD was compensated by higher grain weight and a greater proportion of grain filling per panicle (Bouman and Tuong, 2001).

2.2 Impacts on soil

AWD may be unsuitable in sandy soils as water drains quickly. In heavy clay soils with shallow water tables, AWD may be unnecessary since soil water table depth never drops below the deepest roots (Belder et al., 2004). Soil may shrink and form cracks or macrospores after the disappearance of ponded water in well-puddled paddy fields thereby increasing water requirements and decreased water productivity in clayed soil (Bouman and Tuong, 2001). Cracks in soil increase water percolation as percolation rate are affected by the extent of soil cracking and the depth of ponded water in the rewetting phase (Kirby and Ringrose-Voase, 2000; Cabangon and Tuong, 2000). Nitrogen leaching losses in the system of AWD can be reduced due to a significant decrease in the volume of percolation water compared with CFI (Peng et al., 2011). The soils in rice paddy fields are alternately submerged and non-submerged which induces aerobic and anaerobic conditions. In flooded soils, the normal process of gaseous exchange between the soil and the atmosphere is interrupted (Chowdary, 2004). The soil drying and rewetting cycles in alternate wetting and drying (AWD) irrigation can release phosphorous by physical and biological processes (Dodd et al., 2015). Compared with the soil of CFI, the soil of frequent alternate wetting and drying irrigation induced more mineralization to release some available P under low P usage condition (Haygarth et al., 2010; Jarvis et al., 2007). AWD regime may improve the soil P status after rice heading by improving the proportion of aerobic bacteria (Li et al., 2018). AWD has been proposed to increase resilience to lodging, since the crop may develop deeper roots to access soil water (Yang et al., 2009). However, in heavy soils such as the clays in Agyauli, drying can lead to particle cementation (Rao and Revanasiddappa, 2006) and soil compaction (Sanchez, 1973). This may restrict root growth and more vulnerable to lodging. yield response of plants grown under AWD performed better in more acidic soils and soils with higher organic content (Carrijo et al., 2017).

2.3 Impacts on Nutrition

Soil drying can also affect the availability and uptake of nutrients like phosphorus, which is more available in flooded and anoxic soils (Dobermann and Fairhurst 2000; Kirk 2004). AWD also alter macro and micronutrient availability and uptake in plants. Aerobic growth favor enhanced selenium accumulation in rice, and decrease arsenic uptake (Xu et al., 2008; Norton et al., 2012; Li et al., 2010). Arsenic accumulation is increased in anaerobic soils as the inorganic arsenic is present as arsenite which is readily taken up by plant roots (Brammer and Ravenscroft, 2009). Elevated grain cadmium is problematic for rice grown under more aerobic conditions yet mild and severe soil drying can reduce grain cadmium (Yang et al., 2009; Arao et al., 2009). Reducing cadmium accumulation in the grain must be a priority for any AWD breeding program (Meharg et al., 2013). Remobilization of carbohydrates from stems to the grain could represent another important mechanism of improving grain filling under AWD treatments (Yang and Zhang 2010). The highly dynamic soil environment during AWD (decreased soil oxygen concentrations during flooding and decreased matric potential during drying) will produce dramatic fluctuations in the root synthesis of chemical signals and their transport to the shoot. Flooding seems to increase shoot ACC (1-aminocyclopropane-1-carboxylicacid)status, and decrease shoot ABA and cytokinin status while soil drying increases shoot ABA (and possibly ACC) status and decreases shoot cytokinin status (Kudoyarova et al., 2007; Belimov et al., 2009; Else et al., 2009). Consequently, each hormone has a unique relationship with soil water (or oxygen) status. reported differential responses to physiological and biochemical changes in rice wherein higher activities of ammonia assimilation enzymes (glutamine synthetase, glutamate synthase, and glutamate dehydrogenase) which are the main enzymes involved in plant N metabolism were obtained under intermittent irrigation than under impounded (flooded)condition (Sun et al., 2012).

2.4 Impacts on Water Use

Maintaining a very thin water layer, at saturated soil condition, or alternate wetting and drying can reduce water applied to the field by about 40–70 percent compared with the traditional practice of continuous shallow submergence, without a significant yield loss (Singh et al., 1996). About 40–45 percent of the water normally used in irrigation of the rice crop in the dry season was saved by applying water in small quantities to keep the soil saturated throughout the growing season only without sacrificing rice yields (Bhuiyan and Tuong,1995). A group researcher also reported irrigation water saving of 35% under AWD with a 10% yield increase relative to continuous flooding (Zhang et al., 2009). A study reported irrigation water reduction to only 30% of the irrigation requirements under CF (Devkota et al., 2013). However, they reported a yield reduction of 27 and 40% under AWD during two-year research in north-western Uzbekistan.

2.5 Impacts on Weeds

Periods of drying encourage weed growth. The most common weeds were *Cyperus rotundus* and *Sagittaria* spp. *C. rotundus* (narrow-leaved weed species), was common in intermittent plots whereas *Sagittaria* spp, a broad-leaved weed species, was commonly found in flooded plots. Infestation was most severe at 35 DAT (Days after treatment) second weeding and 50 DAT (third weeding) thereby requiring more labor than the first weeding (20 DAT). There was no extra time required for weeding operation in the AWDI plots compared to the conventional plots (Chapagain et al., 2011). Weed infestation was more serious in AWD plots, which increased the laborer cost for weeding. Due to these excessive weed infestations under the AWD system, farmers probably harvested fewer yields compared to the non-AWD system (Neogi et al., 2018). Permanently flooded rice land tends to have less weed growth than rice land that is not permanently flooded (Mortimer and Hill, 1999). Flooded conditions until about 2 weeks after transplanting discourages the growth of weeds (Richards and Sander, 2014). Infestation of other weeds varies greatly with the depth of standing water, with sedges being severe under dry conditions (De Datta, 1981).

2.6 Impacts on climate

Rice cultivation is a major source of greenhouse gases, methane (CH4), which contribute to about 11% of the global anthropogenic CH4 emissions (Ciais et al., 2013). 97% of CH4 emissions were reduced by implementation of AWD as compared to permanently flooded fields reported that among rice ecotypes (rainfed, upland, irrigated, deep water etc) irrigated rice emits about 70–80% of CH4 from the global rice area, followed by rainfed rice (15%) (Wassmann et al., 2000). AWD reduced the global warming potential (GWP) of CH4 and N2O emissions by 45–90% compared to continuous flooding (Linquist et al., 2014). Nitrification and denitrification both processes are influenced by soil moisture, the greater the soil moisture, the greater will be the N_2O emission (Baggs et al., 2000; Yano et al., 2014; Davidson and Swank,1986). N_2O production decreases under very high moisture contents but in case of moisture alternations in a field with successive moist and dry periods, the N2O emissions increases (Brentrup et al., 2000).

2.7 Impacts on Plant protection

AWD minimizes the incidence of insect pests and diseases compared to conventional treatment. A group researcher found Rice leaf folder (*Cnaphalocrosis medinalis*) as the major pest observed during 30-40 DAT whereas seedling blight (*Fusarium* spp.) as the primary disease (Chapagain et al., 2011). Incidence was less frequent and of lesser severity in AWDI plots as compared to the conventional plots for both cases. Drying events can increase blast (*Magnaporthe oryzae*) incidence which is a major disease of rice that causes a reduction in yields (Bidzinski et al., 2016). A study reported less insect infestation from stem borer in AWD method than one conventional method of rice production (Hasan et al., 2016).

2.8 Impacts on Human Health

Mosquito, a vector of Malaria diseases lay eggs in standing water and the larvae develop in about 7–10 days in a water environment to develop into adult mosquitoes. Multiplication of mosquitoes in rice fields is affected by plant height, water depth, soil, and other environmental conditions as well as cultural practices. Generally, populations of larvae are low after transplanting, at the peak a few weeks later and then decline as the plants reach a height of 60- 100 cm which may be due to physical obstruction of oviposition, increased shade and the establishment of predators in the fields. Mosquito reproduction ceases when the fields are drained before harvest, or may continue at a low level in residual pools (GoonasekeLe and Amerashinge, 1988). The intermittent drying of rice fields was therefore tested for mosquito as far back as the early twentieth century. More rice production with the use of less water from irrigated systems can help humans not only in production but to improve human health too.

3. Conclusion

More rice with less water is vital for water-food security for the increasing population. AWD can help many rice-growing farmers around the world to cope with water scarcity, thus safeguarding their livelihoods. It is an appropriate technology in the context of an energy crisis, water scarcity and environmental concern. Farmers can be benefitted via a reduction in irrigation cost and increasing yield to some extent. It has not been widely adopted, due to the fear of yield reductions and hence demands greater efforts from researchers and extension workers. So, the implementation of this technology is one of the ideas to achieve sustainability in the field of agriculture.

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