Alternate Wetting and Drying Irrigation in Direct Seeded Rice: A Review

S. Porpavai¹, D. Yogeswar²

ABSTRACT

Rice (Oryza sativa L.) is an important cereal food for more than half of the global population. Rice is a major user of fresh water accounting for approximately 50 percent of the total diverted fresh water in Asia. Due to water scarcity and huge hike in labour wage rates, direct seeded rice offers an attractive alternative for future rice production. Thus there is a need to explore alternate techniques that can sustain rice production and are resource conservative. Direct sowing of rice refers to the process of establishing a rice crop from seeds sown in the field rather than transplanting seedlings from the nursery. Direct seeded rice provides an opportunity for earlier crop establishment to make better use of early season rainfall and to increase cropping area. Effect of AWD on direct seeded rice is presented in this review paper. Direct seeded rice is a resource conservation technology as it uses less water with high efficiency, incurs low labour expenses and is conducive to mechanization. Alternate wetting and drying irrigation increased water use efficiency and water productivity of rice.

Key words: Alternate wetting and drying irrigation (AWDI), Direct seeded rice, WUE, Water productivity, Grain yield.

Direct seeded rice is an emerging production system in India due to less need of water, human labour and cost (Singh et al., 2017). Manual transplanting is the most common practices of rice cultivation and takes about 250-300 man hours per ha for transplanting which is roughly about 25 per cent of the total labour requirement of the crop. Hence, less expensive, farmer friendly and labour saving method of paddy cultivation is urgently needed. Due to escalating population there is always growing demand for rice in India. To overcome these difficulties transplanting can be substituted by direct seeding which could reduce labour needs by more than 20 per cent. DSR is the direct sowing of rice seeds either through broadcasting or drilling on well prepared soil in dry condition. Direct seeding in rice is gaining momentum in many places because of higher profit and greater savings on labour and is adopted nearly in about one third of the total rice area of the country. Direct seeding can reduce the labour requirement, shorten crop duration by 7 to 10 days and produce grain yield comparable with that of transplanting rice. FAO estimates that about 4000-5000 litres of water is required by rice to produce one kg of grain. Since water has become increasingly scarce water saving technologies has become a priority in rice research (Raju and Sreenivas, 2008). AWDI methods can end in reducing total water consumption and also improves water use efficiency and nutrient uptake which results in relatively higher grain yield (Zhang et al., 2009). A brief review is made on safe alternate wetting and drying irrigation and its impact on growth and yield attributes of rice and water productivity.

Direct seeded rice

Dry DSR is a type of direct seeding in which dry rice seeds are drilled or dibbled or broadcast on unpuddled soil either after dry tillage or zero tillage or on a raised bed condition.
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DSR was 20 per cent as reported by (Kaur, 2004); Water saving percentage was 30-50 per cent with similar yields to flooded PTR (Yadav et al., 2011) and 30-50 per cent with yield loss of 20-30 per cent (Bouman et al., 2005). Jat et al. (2009) also found reduced water input by 9-24 per cent with DSR in comparison with puddle transplanted rice PTR.

Due to avoidance of transplant injury, DSR is established and mature earlier than PTR without growth delays and hastens physiological maturity and reduces vulnerability to late-season drought Tong (2008).

Liu et al. (2015) observed that yield of dry DSR is similar to grain yield of traditional transplanted and flooded rice ecosystem across different cultivars. About 55 percent human labour, 10 percent machine labour and 33 percent irrigation water was saved in DSR as compared to conventional transplanted rice with minor reduction in rice yield (Vinay et al., 2016).

Alternate wetting and drying irrigation

Alternate wetting and drying irrigation (AWDI) is a water saving technological aspect that decreases the water consumption in rice. In AWDI, irrigation is done by flooding the field after several number of days after the disappearance of previously ponded water (5 or 7 cm). Hence, the field was in alternately flooded and dried condition and was also called intermittent irrigation. There was some lowering in the grain yield in alternate wetting and drying when it was related with yield of rice grown with conventional flooding system (Bouman and Tuong, 2001).

Zhi (2002) explored the impact of AWDI on water use of rice and found that AWDI technique had reduced water use in rice by 7–25 per cent. Tabbal et al. (2002) documented that lesser water consumption and higher water productivity of rice grown under saturated soil conditions as compared to traditional flooded rice system. AWDI practice induced an oxidized condition of soils therefore, soil aeration was improved and harmful matters within the root-zone were reduced and the water-quality from the losses was better than under continuous flooding (Feng and Li, 2002).

Appropriate irrigation practices can resulted in more suitable way for using water in rice production. However the positive feedback of AWDI largely depends on water at optimum time when plant is in absolute necessity of water. But it is difficult to determine the right irrigation timing during the dry period of AWDI due to difference in soil properties viz., soil structure, hydraulic properties viz., movement of water, infiltration, water holding capacity, texture, bulk density and pore space (IRRI, 2004).

The large variability in the performance of AWDI was caused by differences in the irrigation interval to different soil properties and hydrological conditions in addition to varietal influence (Peng and Bouman, 2007). Safe AWDI is an excellent water saving irrigation technology in which irrigation is applied when water depth falls to a threshold level below the soil surface. There is a specific form of AWDI called Safe AWDI that has been developed to potentially reduce water usage by about 30 per cent at the same time its motive is to maintain yields at the level of flooded rice (Bouman et al., 2007).

To solve the crucial problem, IRRI recommended field water tube for monitoring water depth in AWDI technology.

Irrigation through field water tube

Use of Field Water Tube for monitoring the water level drop so that we can easily determine the irrigation timing. The tube is made of 40 cm long PVC pipe with a diameter of 15 cm, perforating on all sides. The tube is placed vertically to 20 cm depth inside the soil in a flat area of the field close to a bund for easy monitoring of water level drop in the tube (Bouman et al., 2005) Tuong (2007) conducted an experiment on the application of field water PVC tube in AWDI water management showed that field water tube worked positively to monitor the water level drop for reporting the right time of irrigation. AWDI which is the applying of irrigation (to standing water depth of 5 cm) when the perched water table falls to 15 cm below the soil surface (Bouman et al., 2007). Sureshkumar and Pandian (2017) reported that field water tube irrigation reduced the total consumption with lesser number of irrigation. This method of irrigation also increased the water use efficiency and productivity of rice. Kulkarni (2011) reported that using of field water tube in AWDI is safe to limit the water use up to 25 per cent without reduction in rice yield. Comparing to farmers practice of continuous flooding, safe AWDI saves 30 percent irrigation water without any reduction in yield. (Lampayan, 2013).

Oliver et al. (2008) found the effectiveness of use of the field water tube (4 cm in diameter of the top and 40 cm in length or height) installed in the field keeping 7 cm length above the soil and the remaining 33 cm perforated zone underneath the surface to measure the depletion of soil water in the field.

Alternate wetting and drying irrigation on growth parameters of rice

Growth parameters refer to the biomass accumulation which can be measured by plant height, leaf area, root and biomass production. The significant effects of irrigation on growth parameters are well documented in rice.

Plant height is increased when rice was irrigated to 5 cm depth on one day after disappearance of ponded water (DADPW) reported by Chandrasekaran (1996). Ramakrishna et al. (2007) observed maximum plant height of rice with continuous submergence (96.8 cm and 99 cm) which was significantly superior over 3 days drainage (91.6 cm and 95.3 cm) but on a par with that of one day drainage (94.8 cm and 96.9 cm) during 2005 and 2006, respectively. Sariam and Anuar (2010) observed significant difference in plant height between irrigation at field capacity and continuous flooding. Rice plants grown under field capacity produced 5.5 percent shorter plants than under flooded conditions whereas at maturity it showed 9-13 percent reduction in height.
All stages showed significantly higher plant height in the treatment which was given irrigation to 2.5 cm depth immediately after disappearance of ponded water at zero day after disappearance of ponded water (DADPW) in comparison to six days after disappearance of ponded water recorded lower plant height (Chowdhury et al., 2014). Balasubramanian and Krishnarajan (2000) observed a significant increase in number of tillers, in plots which received irrigation 5 cm depth at one DAD. Nasir et al. (2014) stated that irrigating the field when water table in the porous tube at 10 cm depletion of water recorded maximum number of total tillers.

AWDI recorded higher dry matter production, which had reported by Maragatham and Martin (2010). Ye et al. (2013) reported that AWDI decreased the plant dry matter before ripening but increased by 4.6 to 4.9% at harvest when compared with conventional flooding. Chandrasekaran (1996) observed the increase in almost all growth parameters like leaf area index, leaf area duration, crop growth rate, dry matter production and relative growth rate when rice was irrigated to 5 cm depth one day after disappearance of ponded water. Leaf area index and crop growth rate (CGR) were better influenced by irrigating the rice crop 2.5 cm depth immediately after disappearance of ponded water over six DADPW but were at par with three DADPW was observed by Chowdhury et al. (2014). Whereas, Show et al. (2014) observed that decrease in tillering, LAI and CGR of the rice crop at AWDI which led to reduced panicle production, grain formation, grain development and ultimately poor crop yield under AWDI practice in summer season as compared to those of continuous saturation.

Alternate wetting and drying irrigation on yield parameters of rice

Superior number of tillers per m² and higher shoot and root length recorded under intermittent irrigation in comparison with 5 cm depth at one day after disappearance of ponded water and 5 cm depth at two days after disappearance of ponded water (Geethalakshmi et al., 2009). Kumar et al. (2013) recorded more number of tillers per m² (145.96) with irrigation of 7 cm submergence depth at one DADPW which had significant difference over irrigation of 7 cm depth of submergence at three days after disappearance of ponded water (130.06) and five days after disappearance of ponded water (113.61).

Irrigation to 5 cm depth at one day after disappearance of ponded water registered higher number of tillers in rice followed by irrigating to 2.5 cm depth at three days after disappearance of ponded water noticed moisture stress effect in the water irrigation regime (Balasubramanian and Krishnarajan, 2000). Ramkrishna et al. (2007) reported that continuous submergence recorded higher number of tillers (14.3 and 14.5) than one day drainage (13.3 and 13.8), followed by three days drainage (12.4 and 13.0) during 2005 and 2006, respectively.

Application of 5 cm depth of irrigation water when water level in the perforated PVC pipe fell 10 cm drop, gave the second higher yield (6.58 t/ha) but realized higher WUE (69.48 kg/ha-cm) indicating quite a large water saving (15 cm) as compared to continuous submergence. Higher productive tillers and panicle length were observed with the rice crop with irrigation to a depth of 5 cm one DADPW (Chandrasekaran, 1996). Jongdee et al. (2002) reported that water restrictions during flowering increased spikelet sterility leading to reduction in lower number of filled grains.

Zhang et al. (2009) reported that rice grain filling rate in AWDI practice was high at the early grain filling stage and low at the late grain filling stage whereas in continuous flooded condition grain filling rate of rice was still high at the late grain filling stage. Likewise, the maximum number of panicles per m², weight of grains per panicle and panicle length was recorded in irrigation after one DADPW and it was statistically at par with irrigation after two DADPW (Sandhu et al., 2012).

Alternate wetting and drying irrigation on yield of rice

Higher rice yield and water productivity was recorded under AWDI practices was reported by Lu and Hirasawa (2000) but Bouman and Tuong, (2001) reported that yield losses was commonly observed under AWDI practice when compared to continuously flooded rice. In general, AWDI increased water productivity due to lower total water input and smaller yield reduction than the amount of water saved. Bouman and Tuong (2001) and Bouman et al. (2007) concluded that 92 per cent of the AWDI treatments tested were resulted in yield reduction varying from 1 to 70 per cent compared to those of the flooded checks. Likewise, Chandrasekaran et al. (2002) concluded that irrigation scheduled to 5 cm depth at one DADPW was optimum to obtain higher yields in rice-rice cropping system.

Higher grain yield (4240 kg/ha) was recorded with daily irrigation (continuous flooding) which was superior to all other irrigation schedules, Kumar et al. (2006). Ramkrishana et al. (2007) reported that continuous flooding recorded 9.6 to 17.4 percent higher grain yield than three day drainage and one day drainage but the number of irrigation and total water consumption of rice were higher under continuous submergence, whereas water use efficiency was higher under 3 day drainage.

Research evidences showed that AWDI saved irrigation water when compared to flooded rice with decrease in yield as soil moisture depletes (Bouman et al., 2001). A parallel work was carried out by Sandhu et al. (2012) also revealed that the maximum grain yield was obtained with irrigation water application at one DADSW (6.99 t/ha), which was statistically at par with the yield obtained with application of irrigation at three DADSW (6.87 t/ha) and tensiometer guided irrigation (6.85 t/ha). Kumar et al. (2014) opined that 10.92 and 14.12 percent higher yield was obtained in 7 cm irrigation at one day DADSW as compared to 7 cm irrigation at 3 and 5 DADSW, respectively.

Intermittent irrigation gave significantly higher grain yield (7110 kg/ha) against continuous irrigation (6750 kg/ha) was
observed by Makarim et al. (2002). Similarly, Paul et al. (2014) revealed that the higher grain yield (5.9 - 6.2 t/ha) was obtained in irrigation scheduling when water level reached 15 cm below ground level which was on par with continuous standing water (5.7-6.0 t/ha) and the lowest (4.6-4.7 t/ha) in irrigation regime when water level reached 50 cm below ground level. Omwenga et al. (2014) revealed that the eight days drying period gave the higher yield of (7.13 t/ha) as compared with the conventional method of rice cultivation (4.87 t/ha) in Kenya. The grain yield was higher under saturated condition (7.6 t/ha) than flooded condition (7.1 t/ha) in Malaysia (Sariam and Anuar, 2010).

Alternate wetting and drying irrigation on water saving

Chapagain and Yamaji (2010) reported that AWDI saved 28 percent irrigation water when compared with continuous flooding. Yao et al. (2012) observed that AWDI saved 24 and 38 percent irrigation water in 2009 and 2010, respectively as compared to CF. Qun et al. (2017) observed increase in both grain yield and WUE by adoption of moderate AWDI irrigation.

Irrigation given once in three to five days with 5 cm submergence coincided with giving irrigation immediately after disappearance of ponded water or one to two days later and registered water saving of 49 percent over the existing practice of continuous submergence was observed by Ganesh and Hakkal (2000). Belder et al. (2004) reported that irrigation water was saved up to 6-14 percent under AWDI. Cabangon et al. (2004) stated that AWDI in lowland rice areas with heavy soils saved the water to the tune of 15 to 20 percent without any adverse impact on yield. Feng et al. (2007) indicated that irrigation water under AWDI reduced to 36.6 and 22.0 percent reduction in total water consumption. Belder et al. (2007) and Bouman et al. (2007) summarized that AWDI reduced total water input by 15-30 percent and produced comparable yield with continuous flooding.

Sureshkumar and Pandian (2017) found that field water tube with intermittent irrigation reduced the total consumption due to lesser number of irrigation. This method of irrigation also increased the water use efficiency and water productivity of rice.

Higher water use efficiency (WUE) of 3.04 kg/ha-mm at continuous saturation level irrigation was recorded by Patel (2000). Chandrasekaran et al. (2002) observed that the WUE of 6.02 kg/ha-mm under irrigation practice of 1 DADPW. Subramanyam et al. (2007) also reported that irrigating rice at 1 DADPW significantly reduced irrigation water use and thereby, increased WUE over continuous flooding. Application of 5 cm irrigation water when water level in the perforated PVC pipe fell 10 cm below ground level recorded higher WUE (69.48 kg/ha-cm) resulting in large water saving compared to continuous submergence (Oliver et al., 2008).

The value of WUE was found to be the maximum with 2.5 cm of irrigation at six DAD and the minimum with 2.5 cm irrigation at zero DAD in SRI method of cultivation (Chowdhury et al., 2014). Anbumozhi et al. (2001) and Huang et al. (2008) observed increased water productivity in AWDI as compared to continuous flooding. (Chapagain and Yamaji 2010) opined that water productivity was significantly higher in the intermittent irrigation (1.74 g/l) under SRI (AWDI) as compared to 1.23 g/l under normal planting with continuous flooding. Maragatham and Martin (2010) also stated the similar results that the AWDI system of rice cultivation recorded the higher water use efficiency (5.66 kg/ha-mm) whereas least water use efficiency was registered in flooded rice. Thin water layer irrigation management, saturated soil condition or alternate wetting and drying could reduce water input to the field by about 40-70 per cent compared to the traditional practice of continuous submergence, without a significant yield loss was registered by Singh et al. (1996). Chandrasekaran (1996) found that higher WUE of 6.02 kg/ha-mm under irrigation practice of one DADPW than flooding irrigation. Water saving of 15 to 20 per cent in rice through AWDI than conventional practice (Cabangon et al., 2004). Whereas, Belder et al. (2004) calculated that evaporation losses in rice fields decreased by 2-33 per cent in AWDI compared with continuously flooded condition. AWDI in lowland areas reported to have lesser total (irrigation + rainfall) water inputs by around 15-30 per cent (Bouman and Tuong, 2007) and Zhao et al. (2010) noticed reduced irrigation water in AWDI by 20-50 per cent compared to continuous flooding of rice crop. Similarly, Kulkarni (2011) reported that using of field water tube in AWDI irrigation was safe to save the water use up to 25 per cent without reduction in rice yield. In wetting and drying water management, re-irrigating the field when plots shows mild stress in AWDI practice reduced irrigation water input by 8-20 per cent and at severe stress by 19-25 per cent as compared to continuous flooding was documented by Cabangon et al. (2011). Mostafazadeh-Fard et al. (2010) reported that decreasing the depth of ponded water on the soil surface in irrigated rice reduced the water use by about 23 per cent.

Alternate wetting and drying irrigation on water productivity

Increased water productivity (1.26 kg/m³) in AWDI plot at 9 cm ponding depth compared to continuous flooding (0.96 kg/m³) was observed by Anbumozhi et al. (1998). In general water productivity in continuously flooded rice typically ranges between 0.2-0.4 kg/m³ of grain water in India. Water saving irrigation practices increases water productivity up to maximum of 1.9 kg/m³ of water but decreases the grain yield (Bouman et al., 2007).

Significantly higher water use efficiency (0.35 and 0.63 kg/m³) and field-crop water-use efficiency (0.42 and 0.37 kg/m³) with three day drainage and one day drainage, respectively and the least were observed with continuous water submergence (0.32 and 0.28 kg/m³) as recorded in the experiment conducted by Ramakrishna et al. (2007). Huang et al. (2008) recorded the higher water productivity
with AWDI irrigation and lowest water productivity with flooded rice. Alternate Wetting and Drying irrigation practice is used to tackle the water scarcity in irrigated rice cultivation and enables more effective water and energy use there by resulted in higher water productivity (Lampayan et al., 2009). Tabbal et al. (2002) reported that maintaining a very thin film of water layer at saturated soil condition or alternate wetting and drying irrigation can reduce water requirement by almost 40-70 per cent compared to traditional practice of continuous submergence without any significant yield loss which resulted in higher water productivity.

**CONCLUSION**

The review revealed that Direct seeded rice has potential to produce slightly lower or comparable yields as that of transplanted rice and appears to be a viable alternative to overcome the problem of water and labour shortage. Nursery raising, puddling and transplanting operations are skipped in direct seeding. Continuous submergence or irrigation on the day of disappearance of ponded water has greater potential to produce more grain yield in direct seeded rice but alternate wetting and drying irrigation had higher water use efficiency with some yield reduction when compared to flooding irrigation and irrigation on the day of disappearance of ponded water.

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