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Short Communication

Water Recycling System: Sustainable Water Management Approach for Paddy Production

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Abstract: Water resources have been impacted by current climate change, as well as increased demands from both traditional and new water users, including municipal, industrial, and agricultural sectors. Thus, recycling water for irrigation to ensure seed production has a significant impact on food security sustainability. In this study, a water recycling system was developed and tested in order to sustain seed production. The study was carried out over eight seasons, from 2014 to 2019, at the Rice Centre of Excellence (CoE) research plot in MARDI Seberang Perai. The system included irrigation and water collection facilities to be reused. This approach was taken to sustain water resources and ensure that paddy cultivation was not affected by weather changes. Data on rainfall and irrigation flow were collected for each season. The field water depth was monitored every two days before irrigation was applied. This system proved that the total water saving for each season studied ranged from 20 to 32 percent, depending on the intensity of the rainfall. More than 3.5 tonnes per hectare of fragrance paddy seed were successfully produced as a result of this study for research and development purposes.

Keywords: Water recycling; irrigation; paddy production

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1. Introduction

Amongst the economy sectors, agriculture is one of the sectors which are most sensitive to water scarcity. Although the agricultural sector is sometimes viewed as a last priority user of water, after domestic and industrial sectors, it accounts for 70 percent of global freshwater withdrawal and more than 90 percent of consumption for irrigated area (Hanafiah *et al.*, 2019). In Malaysia, more than 90 percent of irrigated water is devoted to lowland rice cultivation. The constant increase in demand for agricultural products to satisfy the needs of a growing population continues to be the main driver behind agricultural water use (Amin *et al.,* 2011). Thus, the search for technologies and measures to save and conserve water in irrigated agriculture has intensified. Consequently, many government organizations and research institutions such as *Bahagian Pengairan dan Saliran Pertanian* (BPSP) and Malaysia Agriculture Research and Development Institute (MARDI) are focusing their efforts on developing and implementing various water saving measures in order to produce more food with less water. The first phase of water management typically focuses on increasing water supply, consisting of the development of technology and infrastructure to satisfy increasing water demand. As a means of improving water supply, the options considered were tail water recycling and reuse, groundwater exploration, and increased on-farm water storage (FAO, 2001). On the other hand, to reduce water demand, the technologies options were divided into improved cultural practices that could reduce on-farm water losses, increased efficiency of water use and improved irrigation efficiency (Evans & Sandler, 2008).

Furthermore, in order to have secure access to water while being able to reduce damages by floods and controlling droughts, storing of seasonal and irregular water flows are applied (Budhakooncharoen, 2003). Water storage is perhaps the greatest improvements in water management (Russo *et al.*, 2014). Water can be stored in large dams, on-farm storage ponds or even surface storage such as natural wetland. Besides, recycling or reuse wastewater and drainage water is an alternative to secure more water (Joshua *et al.*, 2017). Storage allows more water availability by capturing water when it is plentiful and making it available for use when there are shortages (Cosgrove and Loucks, 2015). Storage can also be used to balance supply and demand over much shorter periods such as storing the water from river flows during a storm and making it available after the storm. Doing so will allow more water to be made available, and also increases the flexibility of irrigation systems by improving the reliability and timeliness of supplies so that farmers can better schedule their irrigation and reduce water losses.

2. Materials and Methods

A water recycling system for rice cultivation research project was set up in station MARDI Seberang Perai in 2012. The layout of the research plot is shown in Figure 1. It was an enclosed nine-hectare paddy field where all the water that flowed in and out of the field were able to be monitored, measured and recorded. All the required facilities such as pump house, irrigation pipeline, infield drain, conveyance drain, and pond were constructed to conduct the research. The land levelling slope was repaired to increase efficiency of field runoff either from rainfall or irrigation to improve the water collection facilities. This water flows directly to the storage pond. The pond has a surface area of 0.7 ha and a depth of 4 metres. When water was needed, a diesel engine and pump set were used to pump the storage water back into the irrigation system and redistribute it back into the cultivated field. The experiments were conducted consecutively for eight (8) seasons which comprised of both off seasons (OS) and main seasons (MS), i.e., OS 2014, MS 2014/2015, OS 2015, OS 2016, MS 2016/2017, OS 2017, OS 2018, and MS 2018/2019. Data collected for water conservation studies included daily rainfall, daily evaporation, total amount of reuse water, total amount of field runoff, storage pond water level, number of irrigation events, total diesel consumption, and total pumping hours.

Figure 1 represented the water flow cycle through the system built to conserve tailwater from paddy fields by conveying the water to the retention pond via a dedicated drainage system. When water is required, an irrigation system is used to pump it back into the paddy field.

Figure 1. Schematic flow of water recycling system (a) Field water catchment area and irrigated water; (b) Perimeter drain convey water to the recycle pond; (c) Water collected in recycle pond; (d) Pump house facilities for a pipeline irrigation system.

2.1 Crop Water Supply

2.1.1 Field rainfall data collection and pond water measurement for irrigation

Rainfall data was recorded using Davis Vantage Pro2 (Davis instrument, United States) portable weather station that was located near the study area. The gauge was used to obtain more precise information on effective rainfall in catchment areas. For each season studied, rainfall was recorded from planting to harvesting. Rainfall was important as it was the main water source in paddy planting activities. Effective rain is the amount of rainwater that contributes to the need for water for paddy growth. Effective rainfall is when rainwater can be collected and used in rice fields (Shui *et al*., 2006).

Rain should be fully utilised for efficient water use, and paddy field conditions should be repaired to avoid leakage or percolation (Shui *et al*., 2006). The water level in paddy fields was monitored to determine sufficient water requirements or otherwise. If the water in the rice field does not reach the water depth of 5 to 10 cm (Sani *et al*., 1992), the supplement irrigation system was activated to meet the water requirement for paddy cultivation. The field water level was monitored using staffing measurement for irrigation operations. A water flow meter was installed to measure the water used for irrigation. For each irrigation activity, the pumping discharge rate was recorded.

2.2 Seed Production

Crop output is dependent on demand from different consumers, i.e., scholars, suppliers of seeds, etc. Essentially, seed production must comply to the MARDI's standard of practise established in 2002. For this project, the seedling used for transplanting was 12 days old after seeding in the tray on the nursery bed. The single plant was transplanted immediately after the seedlings were removed from the nursery bed and the seedlings were carefully placed in very shallow (1–2 cm) soil in a square pattern with a spacing of 25 cm x 25 cm between rows and hills. Flooded water was supplied continuously with a water level of approximately 5 cm until 14 days before harvest in the direct seed process (Shahida *et al* 2016). The direct seeded plots were received NPK fertilizer at rate 15:15:15 at 21 and 34 days after sowing (DAS) and 12:12:17 at 49 DAS. The weeding activity in the conventional method plots was done by hand at 10 and 20 days after planting (Mohd Fairuz et al., 2019). Combine harvester was used to harvest all the seeds, which were then weighed and recorded at the seed factory in MARDI Seberang Perai.

3. Results

3.1. Rainfall and Water Pumping Rates in 8 Planting Seasons

Rainfall and the amount of irrigation could determine the amount of water used for paddy cultivation at certain times according to season.

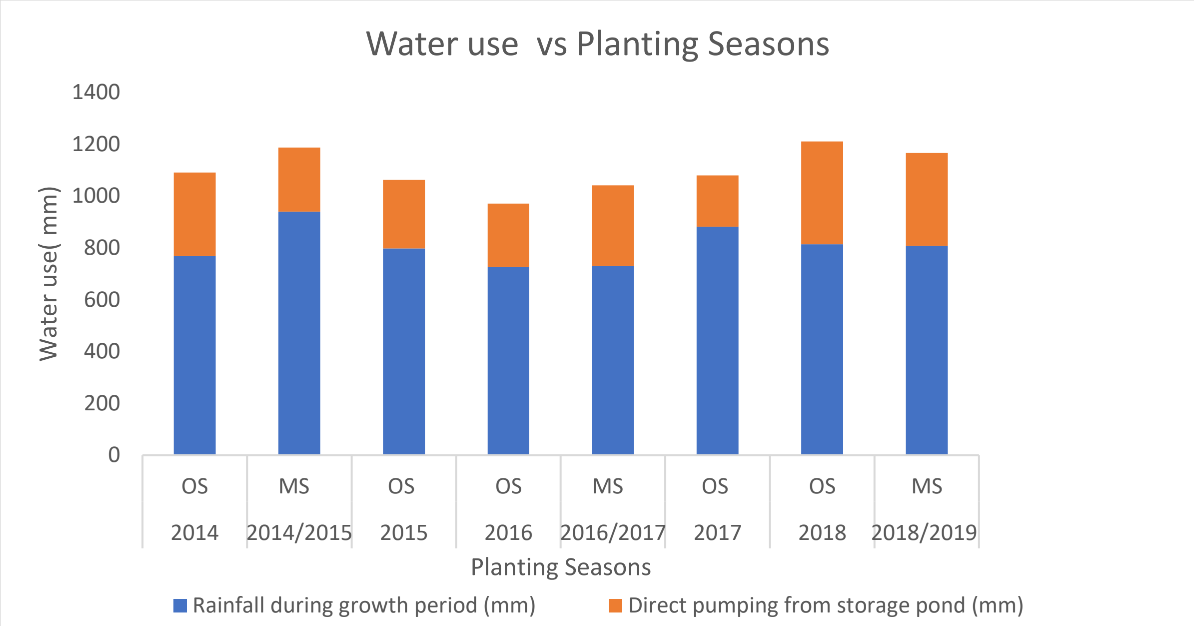

Figure 2. Amounts of water use during the planting season

The field's rainfall distribution and effectiveness, as well as the pumping rate, have been analysed. Figure 2 illustrates the fluctuating amounts of water used along the consecutives planting seasons based on actual weather patterns. The highest amount of water used during OS 2018, with a total of 1209 mm. The substantial rainfall event was the main contributor to the water requirement (813 mm), while another 396 mm or 32.7 percent was supplied from the storage pond. The least amount of water used at OS 2016 which was 970 mm. The cumulative rainfall for the whole season was 725 mm and supplementary irrigation from the recycling pond was 244 mm or 25.2 percent. Due to the low amount of rainfall in OS 2014 and MS 2016/2017, high pumping activity was observed with nearly 30 percent of the water supply being used (768 mm and 730 mm). Meanwhile, the intense rainfall was occurred during MS 2014/2015 and OS 2017, with total of 940 mm and 882 mm, respectively. The event contributed nearly 80 percent of the crop water supply for the entire season, resulting in a 20 percent reduction in pumping activities. Overall, the percentages of water supplied from the storage pond range from 20 to 32 percent as a form of supplementary irrigation, compared to 68 to 80 percent of water supplied from rainfed. According to the study, the total water used for crop water requirements for paddy production reached nearly 1000 mm to 1200 mm per season.

3.2. Correlation of Crop Yield and Water Supply

Figure 3 shows the correlation between yield and water supply at the MARDI Seberang Perai water recycling system from 2014 to 2019. In general, paddy cultivation yielded more than 3.5 tonnes per hectare per season. The yield value was 4.5 tonnes per hectare at the start of the MS 2013/2014 planting season, and it increased slightly to 4.8 tonnes per hectare during the OS 2014. The yield was seen to drop to 4.6 tonnes per hectare and 3.9 tonnes per hectare, respectively, and then rise to 4.1 tonnes per hectare, with the value remaining for the next two seasons (MS 2015/2016 and OS 2016). The lowest yield value was 3.5 tonnes per hectare in MS 2016/2017, which was then increased to 3.8 tonnes per hectare (OS 2017) until the highest yield of 5.5 tonnes per hectare was achieved in MS 2017/2018. The last three seasons produced 3.8 tonnes per hectare, 4 tonnes per hectare, and 4.5 tonnes per hectare, respectively. The less amount of effective rainfall during MS 2016 and 2017 reflected the number of yield (4.1 and 3.5 tonnes per hectare, respectively). However, for MS 2017/2018, nearly 900 mm rainfall was recorded which has produced up to 5.5 tonnes per hectare. Relatively, the yield data recorded from this study has demonstrated that the paddy field in use could potentially produce an average yield (4.25 tonnes per hectare), which is slightly similar to average production yield at Seberang Perai. These findings indicated that the full utilization of water recycling system for irrigation could support the critical stage of crop growth during a water supply shortage or during drought season.

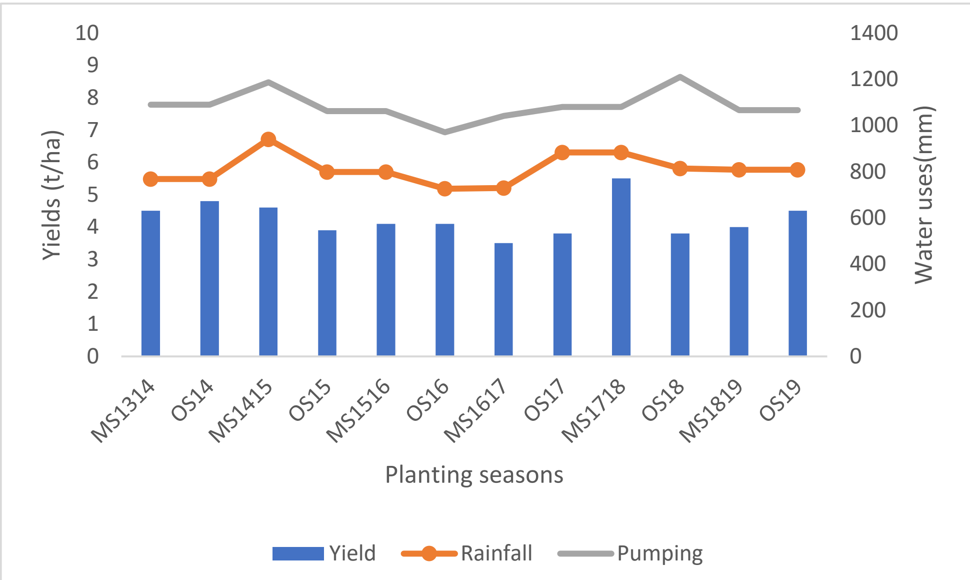

Figure 3. Graph relationship water use and yield.

4. Discussion

Water recycling systems are extremely effective in capturing and reusing irrigation water and rainwater runoff to improve the system irrigation efficiencies. This was demonstrated in studies in which no other water source was required to meet the seasonal crop water requirement other than rainwater and captured field runoff (FAO, 1985). The amount of water saved is determined by the season and rainfall pattern during the crop growth period, as well as soil types and management practices (Pereira & Alves, 2013). According to the results of the experiment, the total amount of water saved from rice cultivation ranged from 20 to 32 percent. More water can be saved during the wet season than during the dry season. This system contributes an average of 4.25 tonnes per hectare of seed per season.

5. Conclusions

The study on water-saving rates for paddy cultivation, which was conducted from 2014 to 2019, showed that this system could reduce dependency on external water supplies. This system will promote positive behaviour among stakeholders and farmers, particularly the importance of conserving water during times of scarcity. The recycling technology, also known as drainage reuse technology, tested in this study can be used by farmers and stakeholders such as consultants, government agencies, and private sectors in agriculture, particularly paddy, to address current and future water shortages. This technology will contribute to systematic irrigation scheduling based on rainfall patterns, crop modelling to identify critical water-stress sensitive growth stages, and can be combined with Internet of Things (IoT) and Unmanned Aerial Vehicle (UAV) to improve water delivery services in irrigation.

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