# Grain yield and water productivity as affected by seedling age and variety under water limited condition

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**Abstract**

On station experiment and farmers' field trial were conducted to evaluate the effect of Alternate Wetting and Drying water saving technology (AWD) on grain yield and water productivity of three irrigated lowland rice varieties in DaikU, Bago Region, Myanmar during the dry season 2015. In both experiments, grain yields were not significantly affected by water regime. However, grain yields were significantly affected by seedling age, and by variety in station. No significant interaction of water and seedling age was observed in Sinthukha variety at both experiments. Grain yields were the highest in 21-day old seedlings and the lowest in 14-day old seedling; highest in Yeanelo-1 and lowest in Hmawbi-2. Under AWD condition, Yeanelo-1 with 30-day old seedling gave the highest yield and water productivity, however, Hmawbi-2 with 14-day old seedling attained the lowest. Water productivity was significantly affected by water, seedling age and variety. The AWD treatment gave the highest water productivity and continuous flooding resulted the lowest. Among seedling ages, 21 and 30-day old seedlings gave the highest water productivity and 14-day old seedling obtained the lowest. The AWD had increased water productivity, although varieties showed variable responses and adaptation mechanism to varying seedling ages.

## Introduction

Rice is the major staple food crop in Asia, where about 92% of the world rice is produced and consumed. Rice is the greatest water user among crops, consuming about 80% of the total irrigated fresh water resources in Asia (Bouman et al. 2007). Water is the single most important component of sustainable rice production, especially in the traditional rice growing areas of Asia. Most of the rice fields are grown as continuous flooded condition. With decreasing water availability for agriculture and increasing demand for rice, water use in rice production systems has to reduce and water productivity increased. Several water saving practices including alternate wetting and drying (Bouman and Tuong 2001) have been identified already and are now being evaluated. Responses and feedback from AWD to save water have been determined frequently in water scarce environments to establish guidelines for effective water management (Tabbal et al. 2002) and proved the water saving of irrigated rice and increasing water productivity in different regions. In Myanmar, total sown area of rice was of 7.2 million hectares with the national average yield of 3.90 t $ha^{-1}$ during 2014-2015 (MOAI 2014). Because of climate change, unreliable rainfall and scarcity in irrigation water during summer, productivity of irrigated lowland rice was very low in Myanmar. There is a need for sound irrigation water management practice that would increase crop water productivity. Besides water saving technology, age of seedlings at transplanting often depended on availability of inputs, including water. In lowland rice, farmers often use 25–50-day old seedlings for transplanting (Singh and Singh 1999). Although there are many reports of the benefits of transplanting younger seedlings, a few researchers have examined the synergistic effect of different adapted varieties on the effect of seedling ages and its subsequent contribution to plant growth under different water regimes. These differences in results may be attributable to the effects of associated crop management practices rather than to water regime alone.

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To fulfill the above requirements, the objective of this study was, therefore, to evaluate the effect of Alternate Wetting and Drying water saving technology on grain yield and water productivity in station and farmers' field.

**Materials and Methods**

The field experiment was conducted at the station of Kadoke Extension Education Camp, Department of Agriculture and 3 farmers' field trials were conducted at Kadokephayagyi Village, Dai-kU, Bago Region during the dry season from December 2014 to May 2015. The experimental site is located 56 kilometers from south west of Bago, Bago Region. The area received an average annual rainfall of 3302 mm and mean temperature of 29°C. The rainfall from January to May is 351 mm while rainfall from June to December is 2951 mm. The

**Table 1. Mean effects of water, seedling age and variety on grain yield. yield components and harvest index of lowland rice in station during the dry season, 2015 .**

| Factors | Treatment | Grain Yield (t ha$^{-1}$) | No. of panicle hill$^{-1}$ | No.of spikelet panicle$^{-1}$ | Filled grain (%) | 1000-grain weight (g) | Harvest Index (HI) |
|---|---|---|---|---|---|---|---|
| Water (W) | CF | 4.62 a | 13.68 a | 97.51 a | 78.63 a | 23.25 a | 0.51 a |
| | AWD | 4.26 a | 13.29 a | 93.46 a | 79.69 a | 23.13 a | 0.50 a |
| | LSD $_{0.05}$ | 1.17 | 1.96 | 11.70 | 9.46 | 0.27 | 0.02 |
| Seedling Age (SA) | 14-day old | 4.23 b | 13.60 a | 86.80 b | 78.00 a | 23.31 a | 0.49 b |
| | 21-day old | 4.60 a | 13.60 a | 99.17 a | 79.71 a | 23.26 b | 0.52 a |
| | 30-day old | 4.49 a | 13.26 a | 100.47 a | 79.76 a | 22.99 b | 0.50 ab |
| | LSD $_{0.05}$ | 0.23 | 1.20 | 10.93 | 5.47 | 0.22 | 0.02 |
| Variety (V) | Sinthukha | 4.45 ab | 14.80 a | 94.62 b | 82.49 a | 21.14 c | 0.52 a |
| | Hmawbi-2 | 4.05 b | 14.33 a | 66.76 c | 80.93 a | 25.65 a | 0.47 b |
| | Yeanelo-1 | 4.83 a | 11.32 b | 125.07 a | 74.04 b | 22.78 b | 0.53 a |
| | LSD $_{0.05}$ | 0.54 | 0.84 | 9.51 | 4.02 | 0.30 | 0.02 |
| Pr > F | W | 0.3139 | 0.4788 | 0.2752 | 0.6773 | 0.1959 | 0.1308 |
| | SA | 0.0164 | 0.7545 | 0.0379 | 0.7122 | 0.0199 | 0.0230 |
| | V | 0.0209 | <0.0001 | <0.0001 | 0.0005 | <0.0001 | 0.0001 |
| | W x SA | 0.0053 | 0.6018 | 0.0868 | 0.6883 | 0.3706 | 0.2927 |
| | W x V | 0.1257 | 0.1448 | 0.9894 | 0.9035 | 0.1225 | 0.1004 |
| | SA x V | 0.6797 | 0.2887 | 0.0797 | 0.5793 | 0.0506 | 0.1386 |
| | W x SA x V | 0.6389 | 0.3971 | 0.0149 | 0.8016 | 0.0275 | 0.5055 |
| | CV $_a$ (%) | 22.53 | 12.39 | 10.46 | 10.20 | 0.99 | 2.60 |
| | CV $_b$ (%) | 6.84 | 11.58 | 14.90 | 9.00 | 1.22 | 5.59 |
| | CV $_c$ (%) | 17.55 | 9.03 | 14.48 | 7.38 | 1.86 | 7.00 |

In each column, means having a common letter are not significantly different at 5 % level.

soil type of the experimental site was silty clay loam soil with pH value of 7.41 and loam soil in farmers' field with pH value of 6.82 - 7.03.

Station experiment was laid out in Split-split plot design with 3 replications; two water regimes (continuous flooding and AWD) as main plot, 3 seedling ages (14-21-30-day old seedling) as sub-plot and 3 varieties (Sinthukha, Hmawbi-2, Yeanelo -1) were assigned as sub-sub plot with two seedlings per hill at 20 x 20 cm plant spacing. Individual plot size was 4m x 5m. After land preparation, each sub-plot was separated by bunds. The bunds were well-sealed using plastic linings installed up to 40 cm to minimize lateral movement of water into and through the bunds. In farmers' field, the same water and seedling age treatments were used with Sinthukha variety only. Each field size was about 2024 $m^2$ with an internal farm ditch.

**Water management**

After transplanting, when the soil was on a saturated moisture condition, field water tubes (FWT) were installed in the AWD plots at a depth of 15 cm below the soil surface. The first irrigation was done 3 days after transplanting and the AWD plots were kept flooded with the regular irrigation for the first two weeks for the seedlings to recover and to establish. Then, after 2 weeks, irrigation water was applied depending on the AWD treatment; whenever there was no water in the field tube in AWD plots, irrigation water was applied until 5 cm depth above the soil surface. All plots were fully flooded (at 5 cm water level) a week before and after flowering. Irrigation input was applied at 5 cm standing water which was measured using a stick gauge. Then, apply AWD again. For continuous flooded plots, water level was maintained 5 cm above soil surface. Total fertilizer rate of 87 kg N $ha^{-1}$, 63 kg $P_2O_5$ $ha^{-1}$ and 63 kg $K_2O$ $ha^{-1}$ were applied.

Grain yield was obtained from the harvest area (6 $m^2$) at center of the plots. Yield components and harvest index were determined in a 12-hill of the

$$\text{Discharge rate}(l/s) = \frac{\text{Volume of the container (Liter)}}{\text{Average time to file the container (seconds)}}$$

$$\text{Water productivity}(kgm^{-3}) = \frac{\text{Grain yield}(kgha^{-3})}{\text{Total water input}\{(\text{Irrigation} + \text{Rainfall})(m^3ha^{-1})\}}$$

Bouman et al. 2007)

sample area. Using GenStat (9th edition), ANOVA and mean comparisons were performed at 5% level LSD.

**Measurement of Irrigation water**

Irrigation water was measured using a flow meter which was delivered to each plot through the flexible hose attached to a pump in station and by using 90° Triangular V notch weir in farmers' field from transplanting to final irrigation. (Majumdar 2002)

## Results and Discussion

**Grain yield and yield components**

In station, no significant effect of water regime was observed in grain yield, yield components and harvest index (Table 1). The high yield, yield components (except filled grain percent) and harvest index were observed in continuous flooding (CF) as compared to AWD. The AWD irrigation using the proposed irrigation schedule of 10 wet days alternated with 10 dry days used less water (29%) without significant reduction in grain yield compared with conventional irrigation (Yamaji 2011). Significant effect of seedling age was observed in grain yields, number of spikelets $panicle^{-1}$, 1000-grain weight and harvest index. Grain yield was the highest in 21-day old seedling (S21), although it is not significantly different from 30-day old seedling (S30). Lowest grain yield was observed in 14-day old seedling (S14) due to initial poor crop growth. Transplanting younger seedlings (14-day) increase mortality of the seedlings in the main field, resulting in a lower yield compared with that of using older seedlings (28-day) (Kewat et al. 2002). However, other studies suggested that use of younger seedlings (8–14 days old) for transplanting results in better crop performance and yield (Pasuquin et al. 2008). Similarly, variety also showed significant effect on grain yield, yield components and harvest index. Yeanelo-1 gave the highest values in yield, number of spikelet per panicle and harvest index followed by Sinthuka and Hmawbi-2 gave the lowest. There was no significant interaction between the factors tested except water regime and seedling age.

The mean values of grain yield were differently observed between the factors tested (Figure 1). The

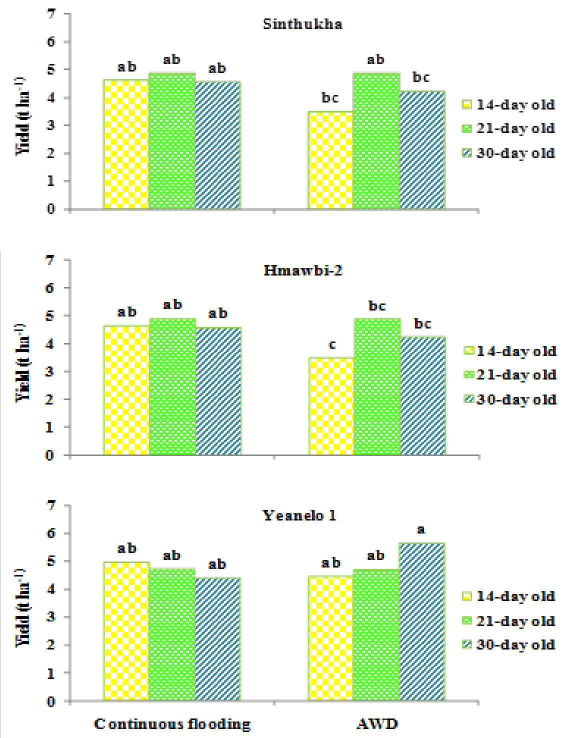


Figure 1. Mean values of grain yield as affected by water, seedling age and variety in station

minimum grain yield was resulted from AWD water regime with S14 in Hmawbi-2. It could be possible due to its longer growth duration and lower number of spikelet per panicle under AWD condition compared with other factors tested. S30 of Yeanelo-1 under AWD regime gave the maximum grain yield, number of spikelets panicle$^{-1}$ which was not significantly different from those of other treatments except those of S14 and S30 of Sinthukha and all tested seedling ages of Hmawbi-2 under AWD water regime. Yeanolo-1 is the most responsive variety to water limited condition due to its still green flag leaf at harvest, better root development and more spikelets per panicle.

In farmers' field, similar results (except variety) of station were observed with respect to effect of water regime on grain yield (Table 2). Some studies indicated that there was no significant reduction in yield between controlled irrigation (alternate wetting and drying) and farmers' practice plots in the Philippines (Lampayan et al. 2004). Seedling age had significant effect on grain yield. There was no significant interaction between water and seedling age. The high yield was obtained in continuous flooding as compared to AWD. The yield was the highest in S21 and the lowest in S14 among the seedling ages. Uneven field leveling and difficulties in transplanting of S14 and high mortality rate in the main field seemed to be less favorable and S21was the most suitable seedling age in the dry season of DaikU under water limited condition.

**Comparison of station and farmers' field**

Grain yield of Sinthukha was not significantly affected by water regime. Variation of grain yield

**Table 2. Mean effects of water and seedling age on grain yield of Sinthukha variety in station and farmers' field during the dry season, 2015**

| Factors | Treatment | Grain Yield (t ha$^{-1}$) | |
|---|---|---|---|
| | | Station | Farmers' field |
| Water (W) | CF | 4.70 a | 3.92 a |
| | AWD | 4.20 a | 3.36 a |
| | LSD $_{0.05}$ | 1.58 | 0.87 |
| Seedling Age (SA) | 14-day old | 4.06 a | 3.49 b |
| | 21-day old | 4.88 a | 3.84 a |
| | 30-day old | 4.40 a | 3.59 b |
| | LSD $_{0.05}$ | 0.89 | 0.15 |
| Pr > F | W | 0.3069 | 0.1065 |
| | SA | 0.1665 | 0.0021 |
| | W x SA | 0.3703 | 0.3033 |
| | CV $_a$ (%) | 17.45 | 11.72 |
| | CV $_b$ (%) | 15.05 | 3.16 |

In each column, means having a common letter are not significantly different at 5 % level.

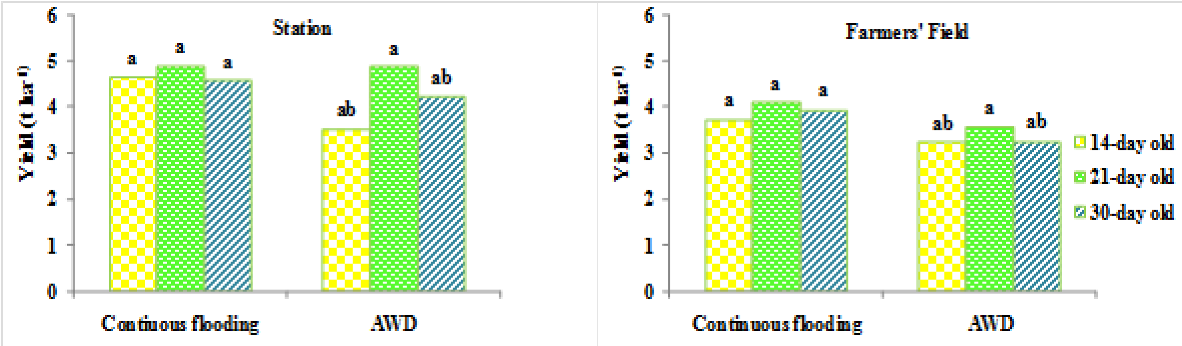


**Figure 2. Mean values of grain yield of Sinthukha variety as affected by water and seedling age in station and farmers' field during the dry season, 2015**

was not significant in seedling age in the station but significant in farmers' field. There were no significant water and seedling age interactions in both experiments (Table 2). Grain yields of both experiments were maximum in S21 and minimum in S14 under both water regimes (Figure 2).

**Water input**

In Station, significant difference of water input was observed between two water regimes. Water input in continuous flooding was significantly higher than that of AWD (Table 3). Several studies have shown that AWD reduces water input significantly without penalty in grain yield (Cabangon et al. 2003).Water input was significantly affected by seedling ages.

The highest water input was observed in S14 followed by S21 and the lowest was observed in S30 due to shorter duration of growth in the main field. Water input was significantly affected by varieties. There was a consistent trend of decreasing water input as the variety changes (Hmawbi 2 > Sinthuka > Yeanelo 1). There were no significant interactions between the factors tested except water regime and variety. Generally, the significant mean effect of variety on water input was observed. Water inputs of AWD water regime for all treatments were significantly lower than those of continuous flooding with decreasing trend in increasing seedling age. In farmers' field, similar findings were observed with respect to water and seedling ages to water input as in station experiment (Table 4). There was no significant interaction between water regime

**Table 4. Mean effects of water and seedling age on water input of Sinthukha variety in station and farmers'**

| Factors | Treatment | Water input (mm) | | Water productivity (kg m$^{-3}$) | |
|---|---|---|---|---|---|
| | | Station | Farmers' field | Station | Farmers' field |
| Water (W) | CF | 1224.20 a | 1132.80 a | 0.38 b | 0.35 b |
| | AWD | 728.50 b | 700.50 b | 0.59 a | 0.48 a |
| | LSD $_{0.05}$ | 26.89 | 66.31 | 0.21 | 0.11 |
| Seedling Age (SA) | 14-day old | 1062.20 a | 975.85 a | 0.39 a | 0.37 c |
| | 21- day old | 955.60 b | 925.25 b | 0.56 a | 0.43 b |
| | 30-day old | 911.40 c | 847.91 c | 0.52 a | 0.45 a |
| | LSD $_{0.05}$ | 37.60 | 23.34 | 0.09 | 0.01 |
| Pr > F | W | 0.0002 | 0.0013 | 0.0493 | 0.0312 |
| | SA | <0.0001 | < 0.0001 | 0.0067 | < 0.0001 |
| | W x SA | 0.0448 | 0.3481 | 0.0233 | 0.0156 |
| | CV $_a$ (%) | 1.36 | 3.57 | 20.72 | 12.52 |
| | CV $_b$ (%) | 2.89 | 1.91 | 13.77 | 2.47 |

In each column, means having a common letter are not significantly different at 5 % level.

**Table 3. Mean effects of water, seedling age and variety on water input and water productivity of lowland rice in station during the dry season, 2015**

| Factors | Treatment | Water Input (mm) | Water productivity (kg $m^{-3}$) |
|---|---|---|---|
| Water (W) | CF | 1226.80 a | 0.38 b |
| | AWD | 777.80 b | 0.57 a |
| | LSD $_{0.05}$ | 15.53 | 0.15 |
| Seedling Age (SA) | 14-day old | 1080.60 a | 0.41 c |
| | 21-day old | 993.00 b | 0.49 b |
| | 30-day old | 933.20 c | 0.52 a |
| | LSD $_{0.05}$ | 16.52 | 0.02 |
| Variety (V) | Sinthukha | 976.40 b | 0.49 b |
| | Hmawbi-2 | 1105.80 a | 0.37 c |
| | Yeanelo-1 | 924.70 c | 0.56 a |
| | LSD $_{0.05}$ | 22.03 | 0.06 |
| Pr > F | W | 0.0001 | 0.0317 |
| | SA | < 0.0001 | < 0.0001 |
| | V | < 0.0001 | < 0.0001 |
| | W x SA | 0.0660 | < 0.0001 |
| | W x V | 0.0025 | 0.0055 |
| | SA x V | 0.7321 | 0.2583 |
| | W x SA x V | 0.1388 | 0.2406 |
| | $CV_a$ (%) | 1.32 | 26.68 |
| | $CV_b$ (%) | 2.14 | 5.73 |
| | $CV_c$ (%) | 3.19 | 19.44 |

In each column, means having a common letter are not significantly different at 5 % level.

and seedling age. The minimum water input was resulted from AWD water regime with S30. Water input has decreasing trend in increasing seedling age under both continuous flooding and AWD water regime. Generally, water inputs of AWD for all treatments were significantly lower than those of continuous flooding and saved water depending on the increasing seedling age.

**Water productivity**

In Station, water regime and seedling age had significant effects on water productivity (Table 3). Water productivity was significantly higher in the AWD than continuous flooding. The highest water productivity was observed in S30 followed by S21 meanwhile the lowest was observed in S14. Water productivity increased with increasing seedling age. Several studies conducted at IRRI from 2007 to 2009 indicated that transplanting older but vigorous seedlings can reduce crop duration in the main field without yield reduction, thus reducing water requirement and increasing water productivity (Lampayan et al. 2013). Variety has significant effect on water productivity. The highest water productivity was observed in Yeanelo-1 followed by Sinthukha while the lowest was observed in Hmawbi-2. Values of water productivity reported by Tuong et al. (2005), who stated that total water input (irrigation plus rainfall) were in the ranges from 0.2 to 1.2 kg grain $m^{-3}$ water. The higher water productivity in Yeanelo-1 was due to shorter crop duration, higher grain yield and lower water input.

There were significant interactions between water regime and seedling age as well as between water regime and variety. The minimum water productivity was resulted from continuous flooding with S14 in Hmawbi-2 variety, which was not significantly different from those of all seedling ages and varieties under continuous flooding. Highest water productivity of S30 of Yeanelo-1 under AWD regime was significantly higher than those of others. Water productivity has increasing trend with increasing seedling age under AWD and no response

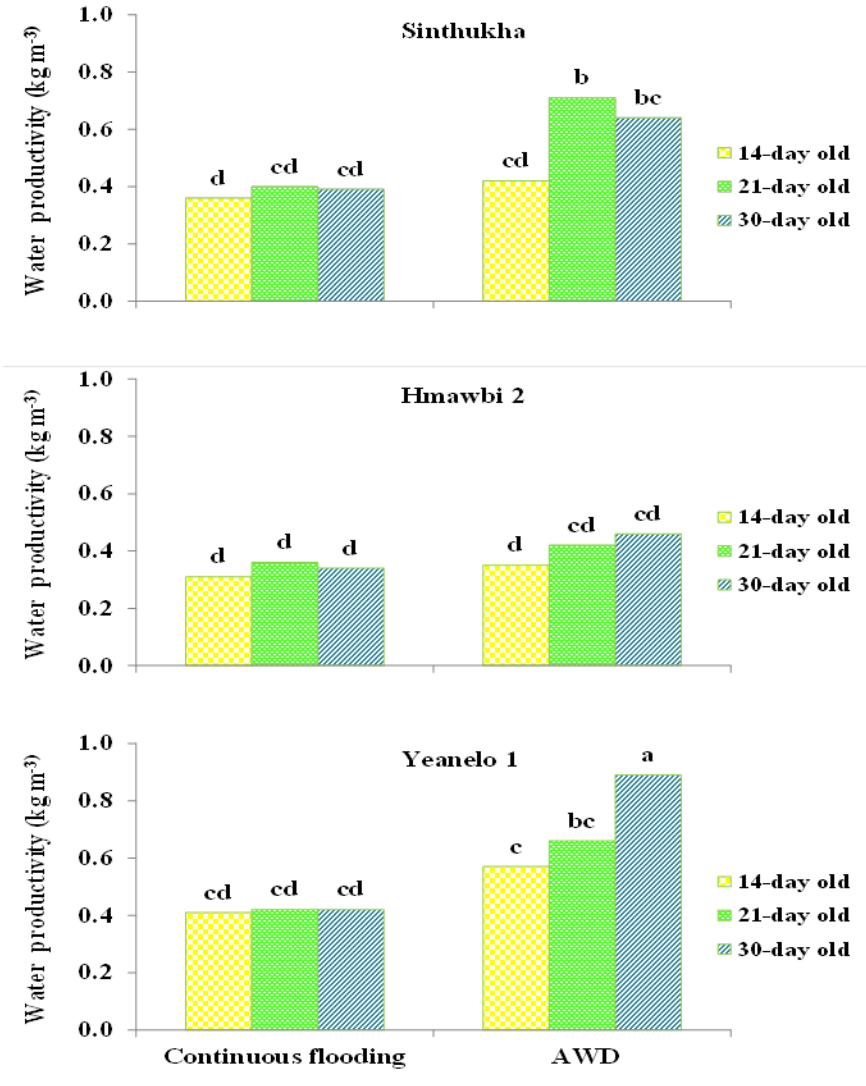


**Figure 3. Mean values of water productivity as affected by water, seedling age and variety in station during the dry season, 2015**

of seedling age in continuous flooded condition (Figure 3).

In farmers' field, seedling age had significant effect on water productivity and significant interaction was observed between water regime and seedling age (Table 4). The significant mean effects of water regime and seedling age on water productivity were observed. The water productivity has increasing trend with increasing seedling age under both water regimes. S30 is more responsive to higher water productivity due to shorter stay in main field and lower water input especially under AWD. Water productivities were higher in AWD than those of continuous flooding in both trials.

## Conclusion

The present study indicated that water regime did not affect grain yield whereas seedling age and variety had significant effects on grain yield. S21 under both water regimes resulted the highest yield in both station and farmers' field. Water productivity in AWD was consistently higher than that of continuous flooding in both experiments; S21 responded the highest water productivity in station and S30 was the highest in farmers' field.

It can be concluded that with the highest yield and with its comparable water input among the varieties, Yeanelo-1 was the most responsive variety for increasing water productivity compared with other two tested varieties to water limited condition. Regarding Sinthukha variety, S21 showed increased productivity under both water regimes. Concerned with Hmawbi-2 variety, high yield and water productivity were resulted except S14 under both water regimes. Therefore, it can be suggested that the AWD water regime with Yeanelo-1 and Sinthkha variety should be used because of its potential to conserve water, increase water productivity without sacrificing grain yield in irrigated lowland rice under water limited condition in DaikU, Bago Region.

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