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PERFORMANCES OF SELECTED WATER SAVING IRRIGATION METHODS DEVELOPED FOR PADDY CULTIVATION IN RED YELLOW PODSOLIC SOILS OF GAMPAHA DISTRICT OF SRI LANKA.

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ABSTRACT

Gampaha District of Sri Lanka is located in Low Country Wet Zone of Sri Lanka. But water scarcity during the yala season cause severe yield reduction in paddy (Oryza sativa) cultivation. Hence, farmers are reluctant to cultivate paddy during yala season at Naiwala of Gampa District. The objective of this study was to evaluate selected alternative water-saving irrigation methods developed for rice cultivation in the yala season on Red Yellow Podsolic soils in the Gampaha district with a view of reducing total water input while ensuring minimum yield reductions. The study was conducted in a rain sheltered plant house. Five water-saving irrigation treatments were imposed as following: Standing water (SW) throughout (T1); SW during vegetative (VEG) and reproductive (REP) stages and saturated soil conditions (SAT) during grain-filling, GF, (T2); SW during VEG followed by SAT during the rest (T3); SW during VEG followed by SAT during REP and allowing to dry down to crack formation (CF) during GF (T4); SAT throughout (T5);

Grain yield and WP showed significant decreases with decreasing water availability. Total dry weight, harvest index and percentage of filled grains showed significant positive correlations to grain yield. All water-saving irrigation regimes cause yield reductions. While ensuring minimum yield reductions, it is only possible to reduce the water inputs during the vegetative stage from standing water to saturated soil conditions. There is scope for increasing water productivity (WP) in rice cultivation on RYP soils in the Gampaha District up to an upper limit of 1.03g kg^{-1} by reducing water input through water-saving irrigation methods.

Key words: Alternative water management strategies, Oryza sativa, water productivity.

1 INTRODUCTION

This research was a continuation of a previous research conducted for Non Calcic Brown soils of Ampara District during 2006 to 2008 (Peiris *et al;* 2015 and Peiris *et al;* 2016). Water scarcity during the yala period of Sri Lanka is major constrains to the paddy production. Not only the Dry zone, certain areas of Wet zone and Intermediate zone also susceptible to this water scarcity. Present study was focused on identifying suitable water management strategies for paddy cultivation in Naiwala area of Gampaha District of Sri Lanka.

Water is becoming a scare resource in all over the world. Per capita availability of water sources declined by 40-60% in many Asian countries between 1955 and 1990. In 2025, per capita availability of water resources in these countries are expected to decline by 15-54% compared with 1990 (Guerra et al., 1998). Hence, it is very important to look at alternative water saving techniques for successful rice cultivation. According to various studies conducted in Asia, continuous submergence is not essential for obtaining higher rice yield (Guerra et al., 1998). Therefore, way of minimizing the amount of water used can be explored by reducing the period of submergence. The present work focuses on finding optimum water management strategies to minimize the period of submergence with minimum adverse effects on yield in the yala season when water is generally insufficient for successful rice cultivation in the yala periods of Sri Lanka.

The primary objective of this study is to evaluate the selected alternative water management strategies for rice cultivation in the yala season on red yellow podzolic soils in Naiwala of Gampaha district with a view of reducing total water input while incurring a minimum yield reduction so that water productivity is increased.

The specific objectives were:

- To determine the impact of different water-saving irrigation regimes on growth and yield of the paddy plant in red yellow podzolic soil.
- To determine the water input and water productivity of paddy under different water-saving irrigation regimes in red yellow podzolic soil
- To identify the stages of the paddy plant grown in red yellow podzolic soil during which water input could be reduced without a significant adverse impact on yield

2 MATERIALS AND METHOD

As this is a continuation of a previous research work, water management strategies were selected from the research findings of Peiris *et al*; 2015 and Peiris *et al*; 2016.

2.1 Experimental Site

The study was conducted in a rain sheltered plant house at the Advanced Technological Institute Gampaha (7^0 09' 57.41" North and 80^0 02' 08.23" East, 46 m above mean sea level) located in Low Country Wet Zone (WL3) of Sri Lanka during year 2014 and 2015. The paddy soil of the Naiwala area (Red yellow podsolic) used for the experiment.

The climate of this region is characterized by a mean annual temperature of 26.95^0C, mean relative humidity of 78.5% and 7 hours of sun shine per day (Source: Department of Meteorology, 2016).

2.2 Planting Material

The rice variety Bg 300, was used for the plant house experiment.

2.3 Treatments And Experimental Design

The five water regimes were used as experimental treatments. The experiment was laid out as a Completely Randomized Design (CRD) with 12 replicate bags per treatment.

2.4 Crop Establishment And Maintenance

Black polyethylene bags of dimensions 35 cm x 20.5 cm x 56 cm were used as bags. Polyethylene bags were filled with Red yellow Podsolic soils of the Gampaha District which were collected from the paddy field of Naiwala area. Approximately 0.04 m^3 of soil was used per bag. All the bags were placed inside the rain sheltered plant house. Basal fertilizer was incorporated at the rate of 55 kg triple super phosphate (TSP) ha^{-1} one day prior to broadcasting according to the recommendations of the Department of Agriculture, 2014. Pre-germinated seeds of Bg 300 were placed in the pots at the rate of 80 kg ha^{-1}. Each of the bags received four pre-germinated seeds. All the bags were labeled randomly according to the treatments and replicates. Saturated soil moisture conditions were supplied until crop establishment. After crop establishment, different experimental treatments were imposed from two weeks after sowing (2 WAS). The different treatments were imposed at panicle initiation (i.e. when maximum tillering was shown) and heading stages which occurred at 4 and 8 WAS respectively.

The first top dressing was applied at the rate of 25 kg Urea ha^{-1} and 35 kg MOP ha-1 two weeks after broadcasting. The second top dressing was applied at the rate of 30 kg Urea ha^{-1} and 45 kg MOP ha^{-1}four weeks after broadcasting. The third top dressing was applied at the rate of 25 kg Urea ha^{-1} and 30 kg MOP ha^{-1} six weeks after broadcasting. The fourth top dressing was applied at the rate of 20 kg Urea ha^{-1} seven weeks after broadcasting Manual weeding was carried out whenever weeds were present.

The experimental treatments were as following:

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Treatment 1 (T1): Continuous standing water (5cm height) up to two weeks before harvesting (Control treatment)

Treatment 2 (T2): Continuous standing water (5cm height) supplied until heading and subsequently keeping the field under saturated soil conditions without standing water until two weeks before harvesting

Treatment 3 (T3): Standing water (5cm height) supplied up to panicle initiation and subsequently keeping the field under saturated soil conditions until two weeks before harvesting

Treatment 4 (T4): Standing water (5cm height) supplied up to panicle initiation and subsequently keeping the field under saturated soil conditions up to heading followed by allowing the field to dry up to crack formation until two weeks before harvesting

Treatment 5 (T5): Field maintained continuously under saturated soil conditions up to two weeks before harvesting

2.5 Measurements

Three hills were maintained per bag and used for the measurements. Growth measurements were taken at maximum tillering, heading, final maturity stages. Four replicates (bags) per treatment were randomly selected for measuring the number of tillers per hill, number of leaves per hill, length and width of leaves, number of panicles per hill (after heading), number of grains per panicle (after heading), oven dry weights of leaf, culm, root and panicle (after heading) using an electric oven by maintaining 60^0C temperature until it reached a constant weight.

Yield and yield component measurements were taken at the harvesting stage using four replicates per treatment. Number of panicles per hill, number of grains per panicle, number of filled grains per panicle, total grain weight, dry weight of the panicle and grain, mean individual grain weight, number of panicles per bag, grain yield per bag were measured in each replicate bag.

2.5.1 Water input

Bags were irrigated according to the respective treatments using a 1 L measuring cylinder. All the water inputs were recorded throughout the experiment.

2.5.2 Soil analysis

A composite soil sample from the experimental site was used to analyze the soil nutrients and chemical characteristics before commencing the experiment.

2.6 Data Analysis

The statistical package SAS (SAS Institute, Cary, USA) was used for data analysis. Significance of treatment differences was tested by Analysis of Variance. To evaluate the significance between treatment means, mean separation was performed with Least Significant Difference (LSD) test at 0.05 probability level. Pearson's Correlation Analysis was performed to estimate the strength of the relationships between growth, yield and water input parameters.

3 RESULTS

3.1 Soil Analysis

Soil analysis and interpretation was based on Agro Service International Method (Porpch and Hunter, 2002). The texture and colour code of the soil was B1 which indicated the soil as light brown with sandy clay loam texture. CEC of the soil was less than 5 meq/100g. Soil pH (4.7) indicated that the acidity of the soil could be ameliorated by adding dolomite. Organic matter content (7.9%)of the soil was adequate as the acceptable range of OM is 3-5% for rice. The EC (647 μS cm-1) level showed that the soil was not saline.

According to the analytical report Iron (Fe^{+++}) content of the top soil was above the respective optimum levels. The ratio of Ca/Mg, Zn, Cu and S were at optimum level. All the other soil nutrients (i.e., K, Ca, Mg/K, Mg, N, P, B, Mn,) were below the optimum requirement and Mg, N, and Mg/P were below the respective requirements.

3.2 Variation Of Leaf Area Per Hill At Different Phenological Stages Of The Crop Life Cycle

Significant differences were not observed in average leaf area per hill among the different water treatments during the vegetative and reproductive phases during 2014 and 2015 (Table 1). During the ripening stage of 2015, significantly higher leaf area per hill obtained by the plants in T2 compared to other treatments. Lowest leaf area per hill noted in plants exposed to more water stress condition during the life cycle (T4 and T5). Similar kind of results were observed in year 2014. But plants of T1, T2 and T3 showed significant higher leaf area per hill and it was only significantly different to leaf area of T4.

Results showed that during vegetative and reproductive period water level for rice cultivation could be reduced from standing water level to saturated water level without affecting to leaf area of the crop.

Table 1: *Leaf Area Per Hill At Main Growth Stages Of The Rice Plant During 2014 And 2015.*

Treatment	Vegetative		Reproductive		Ripening	
	Leaf area per hill (cm^2/hill)		Leaf area per hill (cm^2/hill)		Leaf area per hill (cm2/hill)	
	2014	2015	2014	2015	2014	2015
T1	232.84 a	178.24 a	101.53 a	311.5 a	150.88 a	503.4 b
T2	177.60 a	190.28 a	114.19 a	524.9 a	165.28 a	645.5 a
T3	216.59 a	191. 20 a	116.29 a	485.9 a	147.02 a	385.1 b
T4	122.87 a	170.64 a	116.65a	486.1 a	90.42 b	278.8 c
T5	190.88 a	180.55 a	117.20 a	376.3 a	130.35 ab	291.1 c
CV%	32.12	13	11	13	20	14

Means with same letters are not significant at $p<0.05$

3. 3 Dry Weights Per Hill At Maximum Tillering

Total dry weights, leaf dry weights, shoot dry weights and root dry weight did not varied significantly among the different water management techniques (Table 2). During the vegetative stage except T5 all other treatments received standing water level. However, there were no significant differences in all the dry weights and dry weight ratio. It emphasizes that during the vegetative period standing water level could be reduced to saturated water level without affecting significantly to the crop growth.

Table 3 shows the dry weight and dry weight ratios at maximum tillering stage during 2015. Significant variations were not observed in total dry weight, root dry weight and root shoot ratio. Significant lower leaf dry weight observed in crops exposed to T4 and T5. Significant shoot dry weight also observed in T4 compared to T2.

Overall results of the dry weight and dry weight ratios (Table 2 and 3) reveal that reduction of water level from continuous standing water to saturated level is not significantly effect on vegetative growth of the rice plant.

Table 2: *Mean Dry Weights And Dry Weight Ratios At Maximum Tillering Stage During 2014.*

Treatment	TDW (g/hill)	LDW (g/hill)	SDW (g/hill)	RDW (g/hill)	RSR
T1	2.397 a	0.780 a	1.630 a	1.768 a	0.417 a
T2	1.678 a	0.653 a	1.336 a	0.322 a	0.222 a
T3	1.838 a	0.660 a	1.259 a	0.579 a	0.487 a
T4	1.350 a	0.557 a	1.095 a	0.254 a	0.233 a
T5	1.732 a	0.657 a	1.258 a	0.475 a	0.371 a
CV%	46	32	35	107	105

Within each column means with same letters are not significantly different at p=0.05
TDW - Total dry weight, LDW - Leaf dry weight, SDW - Shoot dry weight,
RDW - Root dry weight, RSR - Root: shoot ratio

Table 3: *Mean Dry Weights And Dry Weight Ratios At Maximum Tillering Stage During 2015.*

Treatment	TDW (g/hill)	LDW (g/hill)	SDW (g/hill)	RDW (g/hill)	RSR
T1	2.14 a	0.48 ab	1.07 ab	1.06 a	0.99 a
T2	2.44 a	0.55 a	1.16 a	1.29 a	1.07 a
T3	2.24 a	0.51 a	1.06 ab	1.18 a	1.13 a
T4	2.29 a	0.44 b	0.95 b	1.38 a	1.48 a
T5	2.19 a	o.44 b	1.00 ab	1.19 a	1.18 a
CV%	17	13	32	32	33

Within each column means with same letters are not significantly different at p=0.05
TDW - Total dry weight, LDW - Leaf dry weight, SDW - Shoot dry weight
RDW - Root dry weight, RSR - Root: shoot ratio

3.4 Dry Weights Per Hill At Heading Stage

All the dry weights and dry weight ratios responded significantly to the water management techniques at heading stage (Table 4). Plants in T1 exceeded other treatments in terms of total dry weight, root dry weight, panicle dry weight and root: shoot ratio at the heading stage. Similar results were shown in T2 with respect to leaf dry weight, shoot dry weight panicle dry weight and partitioning coefficient. Lowest total dry weight achieved by plants in T4 treatment and T2 T3 and T5 were not showed significant variation in total dry weights. Significant higher leaf dry weight achieved by T2 and lowest in T3, while all the other were not showed significant differences. Lowest shoot dry weight showed in plants of T3 and T4 while T1 and T5 did not showed significant variations. Lowest root dry weight showed by T4 and T2, t3 and T5 not showed significant variation in RDW. Higher PDW achieved by the plants of T1 and T2 which received standing water condition during the vegetative and reproductive stages. Significant lower PDW showed by treatments which exposed to saturated condition during heading stage. Partitioning coefficients varied significantly only between treatments. Highest PC achieved by T2 compared to other treatments. Highest and lowest RSR observed in T1 and T2 respectively. Other treatments did not show significant variation in RSR.

Table 4: *Mean Dry Weights Per Hill And Dry Weight Ratios At Heading Stage 2014.*

Treatment	TDW (g/hill)	LDW (g/hill)	SDW (g/hill)	RDW (g/hill)	PDW (g/hill)	PC	RSR
T1	7.657 a	0.814 ab	3.032 ab	4.625 a	0.553 a	0.075 ab	1.483 a
T2	6.110 ab	0.861 a	3.269 a	2.890 ab	0.623 a	0.114 a	0.862 b
T3	5.439 ab	0.633 b	2.298 b	3.141 ab	0.337 b	0.065 b	1.382 ab
T4	4.817 b	0.783 ab	2.558 b	2.259 b	0.316 b	0.065 b	0.827 b
T5	5.396 ab	0.764 ab	2.727 ab	2.669 ab	0.292 b	0.056 b	1.025 ab
CV%	27	17	18	42	24	36	34

Within each column means with same letters are not significantly different at p=0.05
TDW -Total dry weight, LDW - Leaf dry weight, SDW - Shoot dry weight
RDW - Root dry weight, RSR - Root shoot ratio, PDW - Panicle dry weight
PC - Partitioning Coefficient

Except leaf dry weight significant variation in all other dry weights and dry weight ratios were observed at heading stage in *yala* of 2015 (Table 5). Same pattern of variation observed in total dry weight and shoot dry weight. Significant higher TDW and SDW achieved by the crops of T2 compared to T3 which received saturated water condition during heading stage. Significant higher RDW, PDW, PC and RSR were noted in crops of T1 which exposed to continuous standing water condition. Root dry weight and panicle dry weight of T1 was higher compared to T3 and T5. PC of T1 higher compared to T3, T4 and T5 which exposed to water stress condition during heading stage. The lowest RSR was observed in the crops of T3 which exposed to saturated water condition during heading stage. However, RSR of T2, T4 and T5 were not significantly different.

Results shows water stress condition during the reproductive stage, significantly effect on yield by affecting the panicle dry weight and partitioning coefficient. Further it effects on root shoot ratio by reducing the root growth.

Table 5: *Mean Dry Weights Per Hill And Dry Weight Ratios At Heading Stage 2015.*

Treatment	TDW (g/hill)	LDW (g/hill)	SDW (g/hill)	RDW (g/hill)	PDW (g/hill)	PC	RSR
T1	7.02 ab	1.30 a	4.48 ab	2.84 a	0.70 a	0.09 a	0.62 a
T2	8.06 a	1.34 a	5.38 a	2.67 ab	0.59 ab	0.72 ab	0.49 b
T3	5.33 b	1.20 a	4.05 b	1.28 c	0.26 c	0.04 b	0.31 c

T4	6.61 ab	1.26 a	4.37 ab	2.23 ab	0.41 bc	0.06 b	0.52 ab
T5	6.18 ab	1.16 a	4.34 ab	1.84 bc	0.37 bc	0.06 b	0.49 b
CV%	20	21	18	26	34	31	18

Within each column means with same letters are not significantly different at p=0.05
TDW -Total dry weight, LDW - Leaf dry weight, SDW - Shoot dry weight
RDW - Root dry weight, RSR - Root shoot ratio, PDW - Panicle dry weight
PC - Partitioning Coefficient

3.5 Dry Weights Per Hill At The Final Harvesting Stage

Significant differences were observed among treatments in root dry weight, root: shoot ratio and partitioning coefficient at the final harvesting stage (Table 6). However, leaf dry weight, shoot dry weight and panicle dry weight did not show significant treatment differences (p<0.05). Highest root dry weight and RSR achieved by the plants in T1 treatment. There is no significant variation in other plants of other treatments. Highest partitioning coefficient was recorded in T4 while there was no significant variation in other treatments.

Table 6: *Mean Dry Weights Per Hill And Dry Weight Ratio At Final Harvesting Stage 2014.*

Treatment	TDW (g/hill)	LDW (g/hill)	SDW (g/hill)	RDW (g/hill)	PDW (g/hill)	PC	RSR
T1	9.78 ab	0.809 a	3.339 a	1.288 a	4.36 a	0.44 ab	0.406 a
T2	10.65 a	0.604 a	2.389 a	0.468 b	3.59 a	0.33 b	0.178 b
T3	8.92 b	0.825 a	2.658 a	0.904 ab	3.61 a	0.40 ab	0.317 ab
T4	8.17 b	0.565 a	2.509 a	0.422 b	4.06 a	0.49 a	0.155 b
T5	8.85 b	0.617 a	2.349 a	0.385 b	2.87 a	0.32 b	0.162 b
CV (%)	11.7	43	37	65	54	21	48

Within each column means with same letters are not significantly different at p=0.05
TDW - Total dry weight, LDW - Leaf dry weight, SDW - Shoot dry weight
RDW - Root dry weight, RSR - Root shoot ratio, PDW - Panicle dry weight
PC - Partitioning Coefficient

Except panicle dry weight all other dry weight and dry weight ratios were showed significant variation during the harvesting stage at *yala* of 2015 (Table 7). Similar pattern of variation observed in TDW and LDW. Crops of T2 had achieved the highest TDW and LDW compared to other treatments. Highest RDW was noted in T2 compared to T4 and T5 and highest PC showed by the T4 compared to T2 andT3. Highest root shoot ratio achieved by the crops of T2 compared to T5 which exposed to continuous saturated water condition.

Table 7: *Mean Dry Weights Per Hill And Dry Weight Ratio At Final Harvesting Stage 2015.*

Treatment	TDW (g/hill)	LDW (g/hill)	SDW (g/hill)	RDW (g/hill)	PDW (g/hill)	PC	RSR
T1	8.41 b	1.27 b	6.74 ab	1.67 ab	3.41 a	0.40 abc	0.24 ab
T2	10.96 a	1.99 a	8.44 a	2.51 a	4.23 a	0.38 bc	0.31 a
T3	8.49 b	1.29 b	6.78 ab	1.71 ab	3.24 a	0.38 bc	0.24 ab
T4	8.07 b	1.13 b	6.68 b	1.39 b	3.77 a	0.47 a	0.21 ab
T5	8.60 b	1.28 b	7.28 ab	1.32 b	3.88 a	0.45 ab	0.19 b
CV (%)	15.73	18.30	15.68	31.88	22.83	10.67	29.57

Within each column means with same letters are not significantly different at p=0.05
TDW - Total dry weight, LDW - Leaf dry weight, SDW - Shoot dry weight
RDW - Root dry weight, RSR - Root shoot ratio, PDW - Panicle dry weight
PC - Partitioning Coefficient

3.6 Yield Analysis At Harvesting Stage

Except mean individual grain weigh and grains per panicle other yield components, total dry weights and harvest index showed significant variations in the different water regimes (Table 8. The continuous standing water treatment (T1) showed the highest values for all measured variables except total dry weight. Grain yield of T1 significantly different than grain yield of T2, T3 and T4 which experienced water stress conditions at least for a one growth stage. There was a notable yield reduction from T1 to T2 when saturated conditions were maintained (e.g. as in T2) instead of standing water (i.e. as in T1). Total dry weight was highest in T2 and it was significantly different to T3, T4 and T5 treatments. Higher harvest indices were observed in T1and T5 which were significantly different to T2, T3 and T4. Plants of T4 treatment showed significantly lower number of panicles compared to plants of T1, T3 and T4treatments.Significant lower percentage of filled grains noted in T3 compared to other treatments during *yala* of 2014.

Table 8: *Mean Values Of Yield, Yield Components,Total Dry Weights And Harvest Index Per Hill Under Different Water Saving Regimes 2014*

Treatment	Grain yield (g/hill)	TDW (g/hill)	HI	No. of panicle	MIGW (mg)	% of filled grain	Grains per panicle
T1	4.26 a	9.78 ab	0.44 a	2.50 a	17.50 a	94 a	107 a
T2	3.55 bc	10.65 a	0.33 b	2.42 ab	16.50 a	93 a	102 a
T3	2.34 d	8.92 b	0.27 c	2.50 a	15.00 a	62 b	99 a
T4	2.99 dc	8.17 b	0.37 b	2.08 b	16.50 a	85 a	116 a

T5	3.80 ab	8.85 b	0.43 a	2.51 a	16.75 a	82 a	103 a
CV%	12.56	11.7	8.6	9.5	14.3	12.3	24.3

Within each column means with same letters are not significantly different at p=0.05. TDW - total dry weight, HI - harvest index, MIGW - mean individual grain weight

Except grains per panicle, all other yield and yield component showed significant variations in 2015. Treatments which exposed to no water stress (T1) and least water stress condition (T2) showed the highest grain yield compared to other treatments in *yala* of 2015 (Table 9). However, highest total dry weight was achieved by the crops of T2 but it was not significantly different to crops of T1 and T3. Least total dry weight achieved by the crops of T4 and T5 which were exposed to more water stress condition. Interestingly, significant higher harvest indexes were achieved by the T1 and T4 which exposed to no water stress condition and highest water stress condition during the life cycle compared to crops of T3. Significant higher number of panicles recorded in crops of T5 compared to crops of T4 which exposed to continuous saturated condition. Significant variation in mean individual grain weight recorded in crops of T2 compared to the crops of T3. Percentage of filled grains was varied significantly. Highest percentage of filled grains noted in crops of T2 compared to crops of T3 and T5 (Table 9).

Results of the both years indicate that, water stress conditions effect on yield and yield components of paddy plant. However, grains per panicle was not affected by the water level. Out of the water saving irrigation methods, T2 showed the higher performances compared to other water saving irrigation methods.

Table 9: *Mean Values Of Yield, Yield components, Total Dry Weights And Harvest Index Per Hill Under Different Water Saving Regimes 2015*

Treatment	Grain yield (g/hill)	TDW (g/hill)	HI	No. of panicle	MIGW (mg)	% of filled grain	Grains per panicle
T1	4.75 a	9.18 ab	0.52 a	2.25 ab	20 abc	92 ab	112 a
T2	4.14 a	11.06 a	0.37 ab	2.40 ab	22 a	94 a	110 a
T3	3.08 b	9.16 ab	0.33 b	2.55 ab	18 c	59 c	101 a
T4	3.31 b	8.16 b	0.40 ab	2.01 b	19 bc	87 ab	114 a
T5	3.89 b	8.85 b	0.44 a	3.00 a	21 ab	80 b	105 a
CV%	26	14	14	13	9	10	22

Within each column means with same letters are not significantly different at p=0.05. TDW - total dry weight, HI - harvest index, MIGW - mean individual grain weight

3.7 Water Input And Water Productivity

Water productivity was calculated as the ratio of grain yield (in g) over total water input (in kg), including that for land preparation and crop growth (Kijne et al., 2000). Total water input in the treatments of the plant house experiment varied significantly ($p< 0.0001$) in yala 2014 (Table 10). These differences were due to the different water management techniques adopted in the different experimental treatments. The highest total water input was recorded in T1, T2 and T4. During the stage I, lowest amount of water utilized by the T5 which exposed to saturated condition. During the stage II, T1, T2 and T5 showed highest amount of water consumption compared to other treatments. During the stage III, only T1 utilized the significant highest amount of water.

Out of all treatments, T1 had the highest grain yield, and highest total water input. The highest significant water productivity was recorded in T5 (0.99 g kg-1), followed by treatments T1(0.77 g kg-1) and T2(0.68 g kg-1). The yield of T5 was second to the T1 with significant lower water input. Hence highest water productivity achieved by the T5 which continuously exposed to saturated water condition during all growth stages (Table 10). When consider the total water consumption, T1, T2 and T4 showed the significant higher water utilization during the life duration. Plants in T1 and T2 exposed to the lowest water stress conditions and plants in T4 exposed to the highest water stress condition. However, Crops in T4 condition also utilized the similar amount of water as the treatments which received highest amount of water. Significant lower WP were achieved by the crops in T3 and T4 compared to other treatments in 2014.

***Table 10**: Mean Water Input To The Different Experimental Treatments At Different Stages Of The Crop Life Cycle And Water Productivity (WP) 2014.*

Treatment	Mean water input (kg bag^{-1}) sowing to PI (stage I)	Mean water input (kg bag^{-1}) PI to heading (stage II)	Mean water input (kg bag^{-1}) Heading to maturity (stage III)	Total water input (kg bag-1)	WP(yield) (g kg-1)
T1	4.930 bc	7.440 a	3.385 a	16.515 a	0.77 b
T2	5.530 ab	7.205 ab	2.210 c	15.570 a	0.68 b
T3	4.402 c	5.242 c	2.775 b	12.935 b	0.54 c
T4	6.015 a	6.518 b	2.395 bc	15.427 a	0.58 c
T5	2.713 d	7.205 ab	2.315 c	12.678 b	0.99 a
CV%	12	7	11	5	7

Within each column means with same letters are not significantly different at p=0.05

The treatments which exposed to standing water condition in stage I showed the higher water consumption compared to the T5 which received the continuous saturated water condition during *yala* of 2015 (Table 11). Higher water consumption during the stage II were recorded in T1 and T2 which exposed to the standing water level during the stage II. At stage III. Highest water consumption recorded in T11 whereas least in T2, T3 and T4. Highest total water consumption recorded in the control treatment (T1) and least was recorded in T5 (Table 11). Significant higher water productivity was recorded in T5(1.03 g kg-1) and lowest in T1 control treatment (0.69 g kg-1).

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***Table 11**: Mean Water Input To The Different Experimental Treatments At Different Stages Of The Crop Life Cycle And Water Productivity (WP) 2015.*

Treatment	Mean water input (kg bag^{-1}) sowing to PI (stage I)	Mean water input (kg bag^{-1}) PI to heading (stage II)	Mean water input (kg bag^{-1}) Heading to maturity (stage III)	Total water input (kg bag^{-1})	WP(yield) (g kg^{-1})
T1	3.55 a	8.40 a	7.44 a	20.81 a	0.69 c
T2	3.92 a	8.19 a	3.88 bc	16.95 b	0.73 b
T3	3.73 a	4.37 b	3.82 c	12.75 c	0.72 b
T4	3.77 a	4. 25 b	3 81 c	12.44 c	0.79 b
T5	2.27 b	4.11 b	4.13 b	11.37 d	1.03 a
CV%	10	3	4	3	4

Within each column means with same letters are not significantly different at p=0.05

6.4 DISCUSSION

Alternative water management strategies for rice, save water when compared to continuous submergence of soils. However, their effects on grain yields vary widely (Belder *et al.,* 2004). Similarly, in this study different water management strategies had different magnitudes of yield reductions when compared to continuous submergence or the control treatment.

According to the results, water stress conditions were not much effect on growth of the rice plant during the vegetative stage. In this experiment plants in T5 exposed to the saturated water condition during vegetative period. Growth performances of the crops of T5 similar to the other treatments that received standing water condition. Hence, rice plants can tolerate saturated water level and contribute for the growth as standing water level. However, during reproductive and harvesting stage water stress conditions effect on growth of rice plant. Results agree with the findings of Yadav *et al.,* (2011).

In this study yield was higher in the control treatment (T1) and T2 which exposed to least water stress condition than the other treatments. This reveals that water stress effects on yield, total dry weight. Highest total water input recorded in plants of T1, T2 and T4 treatments in 2014. In 2015 highest total water input recorded in T1 and other treatments showed reduction in water consumption in respect to the severity of water stress condition. When comparing the total water input and grain yield, T1 obtained the highest yield with higher water consumption in both years. The yield of T5 was second to the T1 with significant lower water input in 2014. In 2015, yield of T5 was not significantly different to yield of T3 and T4. But T5 had consumed the lowest amount of total water. Hence highest water productivity in red yellow podzolic soil achieved by the T5 which continuously exposed to saturated water condition during all growth stages in both years. In 2014 water productivity of T5 was 0.99 g kg^{-1} and in 2015 it was 1.03 g kg^{-1}.

When compare the present study with the previous findings, there is a deviation in water productivity with the soil type. Water productivity in non calcic brown soils of Ampara district varied from 0.508 – 1.192 g kg^{-1} in 2007 and 1.027 – 1.458 g kg^{-1} in 2006 (Peiris *et al;* 2016). Same experiment in a rain sheltered plant house showed lower (0. 67g kg^{-1}) water productivity (Peiris *et al;* 2015).

This reveals that different soil types respond in diffwrent way to different water management strategies. When selecting a suitable water management strategies for paddy cultivation, soil type is an important factor to be considered.

CONCLUSIONS

All water-saving irrigation regimes cause yield reductions in rice in the yala season in RYP soils in Gampaha District of Sri Lanka. While ensuring minimum yield reductions, it is only possible to reduce the water inputs during the vegetative stage from standing water to saturated soil conditions.

Out of three stages PI to heading (reproductive stage) and heading to maturity (ripening stage) are the most critical stages which require adequate amount of water for higher yield production.

There is scope for increasing water productivity (WP) in rice cultivation on RYP soils in the Gampaha District up to an upper limit of 1. 03g kg-1 by reducing water input through water-saving irrigation regimes. Out of the four water saving methods T5 (Field maintained continuously under saturated soil conditions up to two weeks before harvesting) and T2 (Continuous standing water (5cm height) supplied until heading and subsequently keeping the field under saturated soil conditions without standing water until two weeks before harvesting) can be used as water saving techniques for RYP soils of Gampaha district during *yala* season.

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