# Identification of Suitable Irrigation Interval for Paddy Based on Growth and Yield to Adapt Water Shortage Problem in Ampara District of Sri Lanka

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***Abstract*** *– Field trials were conducted at Rice Research Station, Sammanthurai during "Yala" season 2017 to evaluate the effects of irrigation intervals (7, 10 and 14 days) ongrowth and yield parameters of rice varieties Bg 250 (Short duration) and Bg 94.1 (Long duration) in order to cope with water shortage problem in irrigation schemein th study area.The trial was performed as pot experients as it was difficult control irrigation intervals in the Field. Experiment was designed as factorial treatment in randomized complete blocks design with six treatments and three replicates. The germinated seeds were established in the 40 cm diameter and 30 cm depth of 18 pots. The results showed that the Bg 250 produced 2967.30 ± 90.92 kg/ha which is 27% higher yield than Bg 94-1with the application of water at 7 days irrigation interval. The Bg 250 produced 2589.50 ± 350.83 kg/ha (18% higher yield) grain yield with the 10 days irrigation interval. Cost of irrigation was calculated as labour cost for irrigation arrangement per day and the cost of irrigation.Bg 250 was 17.6 % and 16.7% lower than the cost of Bg 94-1 when water was applied at 7 days and 10 days irrigationinterval, respectively. The grain yield was significantly different between the rice varieties Bg 250 and Bg 94-1 where the Bg 250 was produced higher grain yield in all three irrigation intervals. Therefore Bg 250 can be recommended for "Yala" season in Ampara District with the application of water at irrigation intervals 7 days and 10 days interval to deal with the shortage in water that is being faced currently in Ampara district farmers now and in the foreseeable future.*

***Keywords:*** *Rice, Irrigation interval, Grain yield, Drought, Cost of irrigation, Variety*

## 1 INTRODUCTION

Rice is the dominant crop in Ampara district which has tremendous potentials for increasing its rice production. In rice cultivation, irrigation facilities plays a major role as during *Yala* season in Ampara district. Therefore when selecting a rice variety for cultivation, the most important criterion is the duration of the crop or crop needs less water. Short term rice varieties require less amount of water than the long term varieties. Irrigation interval is of the most important ways to saving irrigation water without reducing rice areas. Irrigation interval is influencing on the growth and the yield of the rice crop, during the "*Yala*" season in Ampara, the irrigation department schedules limited water for irrigation to the paddy cultivation areas due to insufficient water. This situation is worsening due to impact of climate change on temperature and rainfall especially in the dry zone of Sri Lanka. HadCM3 the general circulation model prediction for 2050s indicated that there will be decrease in rainfall in dry zone areas where paddy cultivation is predominant and the increased in temperature will increase the soil moisture deficit

drastically. As the result the paddy irrigation requirement will be increased by 38% for the worst scenario (A2) (De Silva *et al*, 2007). Therefore there is an urgent need to study the possibilities to use the limited water for paddy irrigation requirement as an adaptation to temperature and water stress due to climate change and to achieve the potential yield to feed the growing population (MOE, 2011).

Irrigation plays a vital role in paddy production in Ampara district. The major, medium minor and seasonal irrigation projects were implemented for developing the paddy sector in the district. Several government institutions are involved in irrigation water management.

This research is to highlight the recent trends in irrigation water management through the application of water at different irrigation interval to the long term (Bg 94-1) and the short term (Bg 250) rice varieties. In this study, short term and the long term paddy varieties were taken for analyzing the growth and the yield parameter through applying water at different irrigation intervals. Bg 250 is an improved Sri Lankan rice variety with high quality grains, resistance to leaf blast, bacterial leaf blight, trips and brown plant-hopper. This is an ultra-short duration variety that matures in about 80 days. Bg 250 requires less water requirement than other long term varieties and it is suitable for drought areas. Department of Agriculture in consultation with Irrigation Department too recommend short term variety based on irrigation requirement (Minutes of the DAC meeting in *yala*, 2017). But farmers in these areas are used to cultivate the long duration variety without proper knowledge on climate change impacts and irrigation water requirement. Therefore this experiment was designed to study the growth and yield of short and long duration rice varieties with three possible irrigation interval adapted in Ampara District. The findings will help to farmers to select the better choice to increase the yield.

### Objectives

- To evaluate the growth and the yield parameters of rice varieties (Bg 250 and Bg 94-1) with the application of water at three different period of irrigation intervals during "*Yala*" season in Ampara district.
- To evaluate marginal saving of irrigation water and the cost of irrigation.
- To evaluate the yield advantages or yield losses and net profit with the application of water at different period of irrigation intervals.

## 2 METHODOLOGY

This experiment was conducted at the Rice Research Station, Department of Agriculture, Sammanthurai which is located in the Ampara district of Sri Lanka. The location is classified under the agro-ecological zone of Low Country Dry Zone. Dry season prevails in the months of May, June, July and August is called *Yala* Season and no rains during this period. Second inter-monsoon and Northeast Monsoons brings rains from October to February which is *Maha* season. The mean temperature of the location is 30° C. Highest temperature is 36°C. The lowest temperature is 24°C during December and January periods. Annual average rainfall is 1400mm (District Secretariat Profile, Ampara, 2014). The soil type of the experimental area is classified as sandy loam which is the dominant soil type of the Ampara district.

This research was conducted in pots as the irrigation intervals cannot be controlled in the field. The germinated seeds were established in the fourty cm diameter and thirty cm depth of 18 pots and each pot has 12 plants. Conditions in the pots were made similar to the field conditions. Because it was pot experiment this research study was carried out twice during the '*Yala*' season of the year 2017.

The rice varieties Bg 250 (V1- Short duration /80 days) and Bg 94.1 (V2- Long duration/105 Days) were used for this study because Department of Agriculture and the Irrigation Department recommended short duration (two and a half to three months) variety during *Yala* season and whereas farmers usually use long duration variety. Therefore, short term variety (Bg250) and long term variety (Bg 94-1) were selected for this study (Table 1). Growth and yield parameters of the two rice varieties were observed with the application of water at three different periods of irrigation intervals such as once in 7 days interval (I1); once in 10 days interval (I2); and once in 14 days interval (I3). Total water requirement for short and long term variety were calculated for the study area and divided according to the irrigation interval to be applied to the pots. Four litre of water was applied to each pot at each irrigation interval.

The experiment was conducted with 6 treatments 3 replications (2 Rice varieties and 3 irrigation intervals); the treatment T1 was taken as control treatment which was recommended by the irrigation department for *Yala* season 2017. The experimental design was two factors in a factorial treatment with Randomized Complete Block Design (RCBD). A total number of 18 pots were used for this experiment. Each pot consisted of twelve plants.

**Growth parameters**

*Germination rate*

Germination rate was recorded from both rice varieties Bg 94-1 (Long term rice variety) and Bg 250 (Short term rice variety). The seeds of Bg 94-1 and Bg 250 were pre-soaked before showing to the pots.

*Number of tillers per plant*

Three plants were randomly selected from each replicate of the treatments during the ripening stage. The total number of tillers was counted from the selected plants.

*Plant height (cm).*

Three plants were randomly selected from each replication and measured manually by using the measuring scale. The height was measured from the base of the main stem to the top of the canopy.

**Yield parameters**

*Panicle length (cm)*

Three plants were randomly selected from each replicates. The panicle length of each plant from the selected plants was measured from the base of the lowest spikelet to the tip of the latest spikelet on the panicle, excluding the awn.

*Number of filled grain per panicle*

A number of three panicles were randomly selected from each replication. The number of filled grain was counted and recorded.

*Weight 1000 grain (g)*

The weight of thousand seeds from the selected plant was measured by an electronic balance.

*Biomass weight (g)*

Total biomass weight (entire plant weight including the roots) was taken from three plants from each replicate and fresh weight of the total plant was immediately measured by using electronic balancer.

**Table 1: Treatment of the experiment**

| Treatment Notation (T) | Name of the Treatment |
|---|---|
| T1<br>Control | Variety Bg 94-1/ Long duration variety /3 ½ Month with<br>Once in 7 days irrigation interval(Irrigation Department schedule) |
| T2 | Variety Bg 94-1/ Long duration variety /3 ½ Month with<br>Once in 10 days irrigation interval |
| T3 | Variety Bg 94-1/ Long duration variety /3 ½ Month with<br>Once in 14 days irrigation interval |
| T4 | Variety Bg 250/ Short duration variety/ 2 ½ Month with<br>Once in 7 days irrigation interval |
| T5 | Variety Bg 250/ Short duration variety/ 2 ½ Month with<br>Once in 10 days irrigation interval |
| T6 | Variety Bg 250/ Short duration variety/ 2 ½ Month with<br>Once in 14 days irrigation interval |

*Days to maturity (days)*

Three plants were randomly selected from each replication and observed maturity period of both rice varieties V1 and V2. Each variety were defined with their maturity periods as 85 days and 105 days. Physically, the grain was observed with their filling structure, texture and the colour to decide the maturity.

*Harvest index*

It is used in agriculture to quantify the yield of a crop species versus the total amount of biomass that has been produced. Harvest index can apply equally well to the ratio of yield to total plant biomass.

*Yield (kg/ha)*

Collected seeds after the harvesting left for drying under sunlight. Weights of the seeds were measured and convert in to kg/hectare. According to the pod size, the grain yield were calculated and the quantity convert as kg/ha.

**Irrigation parameters**

*Cost of irrigation (Cost/acre) Rs.*

Irrigation cost for the two varieties were taken to analyst the cost and benefit margin as economic cost effective on the yield with the application of different irrigation intervals. Irrigation cost is the labour cost for irrigation arrangement for each irrigation interval.

All the data were collected for the experimental purpose were analyze statistically using ANOVA with SAS package (University version). Analysis of Variance Technique was applied to test the significance of the treatments.

## 3 RESULTS AND DISCUSSION

### 3.1 Growth parameters

**Germination rate**

Germination of the rice variety Bg 250 was the highest germination rate (90.00%) and rice variety Bg 94-1 was obtained lowest (84.33%). Consequently, the germination rate of both rice varieties was established with better germination rate. The result of the study that states the long and short duration rice varieties were produced more than 85% of germination rate except the treatment T1 which was indicated 84.33% as lowest germination among other treatments. The pre - soaked seeds were performed better germination in this experiment. Priming or pre-soaked of rice seeds might be a useful way for better seedling establishment (Singh *et al*., 1996). Seed priming produces more vigorous, faster, and uniform seedlings and their establishment (Singh *et al*. 1996).

**Plant height (cm)**

There was significant different between the control treatment (T1) and treatments T2 and T6 on the plant height but there was no significant different ($P<0.05$) with the application of water at irrigation intervals among the selected rice varieties (Figure 1). Treatment T2 (67.83 ± 3.00 acm) was recorded as highest plant height among other treatments. Treatment T1 (62.13 ± 2.46 bcm) was recorded as lower plant height (Figure 1). Treatments T2 and T6 were not significantly different as well as treatments T3, T4 and T5 were not significantly different. Long duration Rice variety under the treatment T2 and the short duration rice variety under the treatment T6 were produced similar outcome with the application of water at irrigation interval of 10 days and 14 days (I3). The interaction effect on the plant height were not significantly difference ($P<0.05$). These results are consistent with the reports of Tuong and Bouman (2003) that water stress reduced plant height. Similar findings were reported by Tuong *et al* (2005) wherein decreasing irrigation interval and increasing depth of irrigation in rice production produced greater plant height.

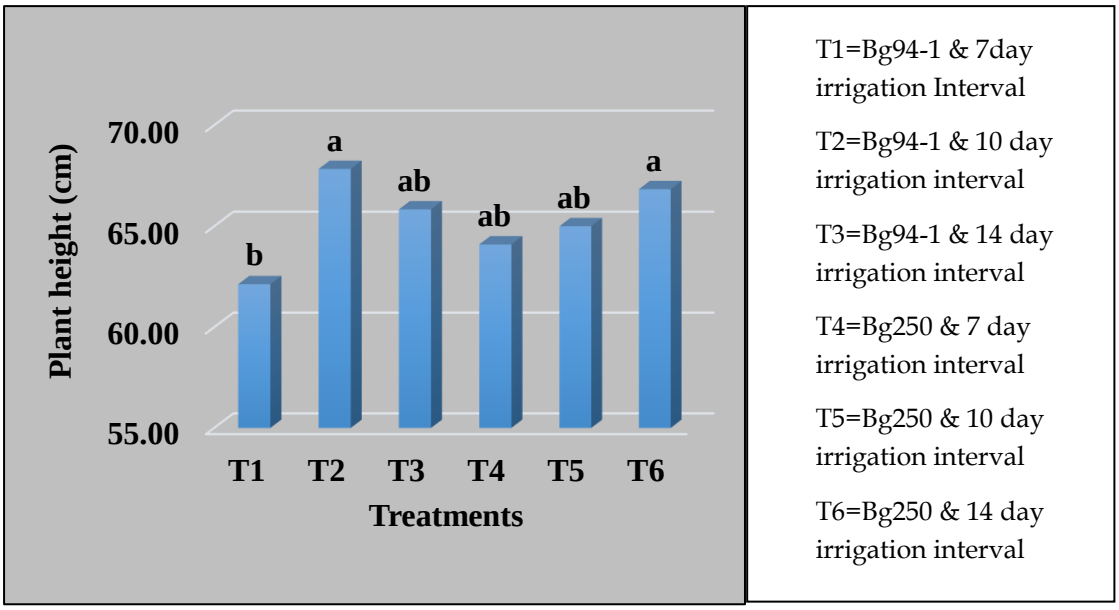


**Figure 1: Average plant height for the different treatments**

**Number of tillers per plant**

The production of tillers was significantly different ($P<0.05$) between the treatments. The treatments T1 (3.67 ± 0.23), T2 (3.87 ± 0.31) and T3 (4.20 ± 0.53) were similar effect on the tillering and treatment T3 has obtained highest number of tillers. The treatments T4 (2.00 ±0.36), T5 (1.67 ± 0.46) and T6 (1.87 ± 0.31) were the similar effect on the tillering and treatment T5 was obtained lowest number of tillers (Figure 2).

Short and long duration rice varieties were significantly influenced on the tillering. The long duration rice variety which was cultivated under the treatment of T1, T2 and T3 were produced significantly higher number of tillers than the short duration rice variety which was cultivated under the treatments of T4, T5 and T6. Tillering was exhibited in same growth duration in both varieties.

There was non-significant effect of the application of different period of irrigation intervals, such as, once in 7 days, once in 10 days and once in 14 days on the formation of tillering in short and long duration rice varieties. And also, the interaction effects of variety and the irrigation intervals was not statistically significant. Therefore, as a result of the experiment that the selected short and long duration rice varieties were significantly affect the tillering.

Excessive tillering leads to high tiller abortion, poor grain setting, small panicle size, and further reduced grain yield (Razaei & Nahvi, 2007). This study states that the genetical variation of the rice varieties influences on the number of tillering. Different varieties significantly influenced the number of tillers; similar results have also been reported by Razaei and Nahvi (2007). The tiller capacity of rice plants varies with variety, plant spacing, fertility, weed competition and damage from pests.

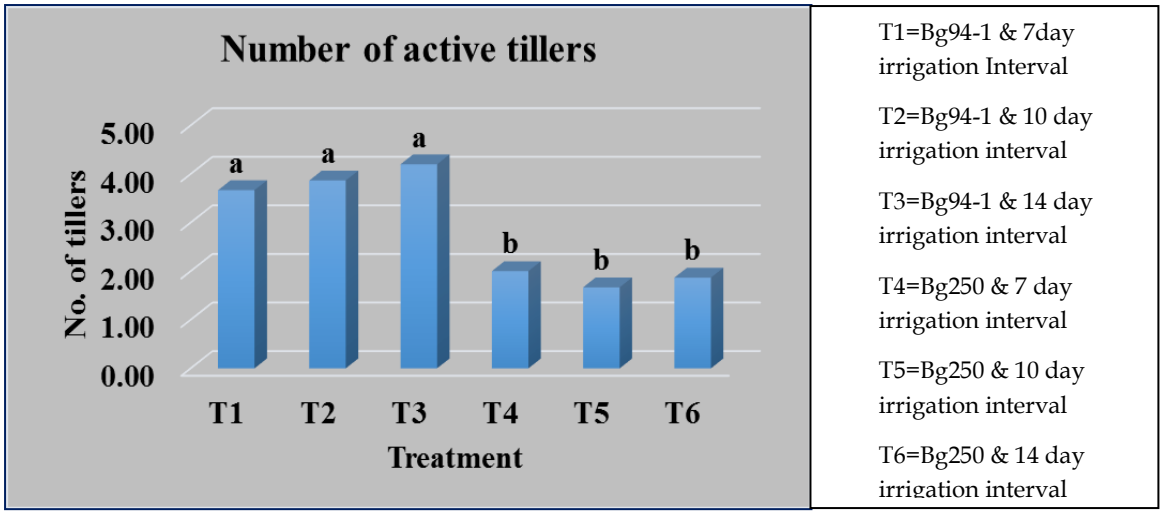


**Figure 2: The average number of tillers per plant for different treatments**

## 3.2 Yield Parameter

### Panicle Length (cm)

Panicle lengths were significantly different (P≤0.05) within varieties for different irrigation interval. The treatment T3 (21.40 ± 1.04 a cm) obtained highest panicle length which is representing the long duration rice variety. T3 treatment of 14 day irrigation interval treatment is significantly different from T1 treatment of 7 day irrigation interval. The treatment T6 (16.40 ± 0.17 c cm) was obtained lowest panicle length which is representing the short duration rice variety (Figure 3). Both short and long duration rice varieties were significantly influenced on the panicle length. There was no significant different (P<0.05) on panicle length with the application of water at different irrigation intervals within short duration variety. Panicle length was not significantly affected by the interaction effect of variety and irrigation intervals.

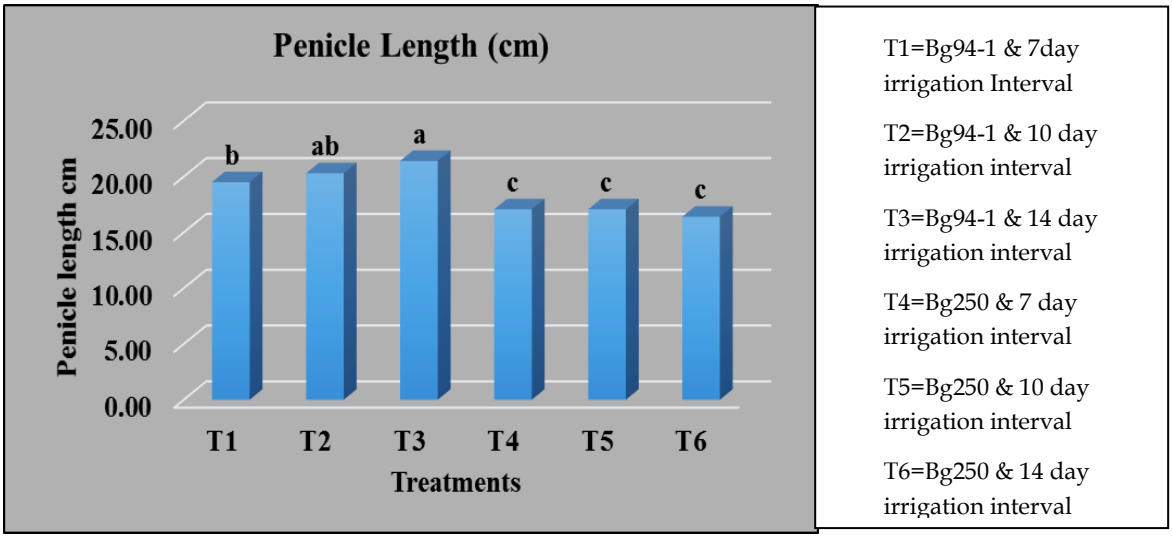


**Figure 3: Average panicle length of the treatments Means with the same letters do not differ significantly (p<0.05)**

According to the study that the genetical characters which influenced on the panicle length. Basically, long duration rice variety produces higher length of panicle than the short duration rice variety. Panicle number per $m^2$ was positively related to maximum tiller number per $m^2$, but not to panicle-bearing tiller rate. This result supports the findings of Huang *et al* (2010). Such findings might be due to the genetic make-up of the varieties though Babiker (1986) observed that panicle length differed due to the varietal variation.

**Number of filled grains per panicle**

The treatments were not significantly different ($P<0.05$) between the treatments. The maximum number of grains panicle per plant (26.50 ± 10.95) was obtained from the treatment T2 with long duration variety and the minimum number of grains panicle per plant (18.50 ± 3.82) was obtained from the treatment T6 with short duration variety. The total number of grains per panicle was not significantly influenced by the duration of rice varieties.

The grains per panicle were non-significantly affected by the different irrigation intervals. The total numbers of grains per panicle was non- significantly influenced by the interaction effect between two varieties and different irrigation intervals. Similar result was reported by Faraji *et al* (2011).

**Weight of 1000-grains (g)**

The weight of 1000-grains was influenced by the different treatments and there was significant different ($P<0.05$) between varieties. The highest weight of 1000-grains was obtained from the treatment T2 (24.68 ± 0.46 a g) of long duration variety and the lowest weight of 1000-grains was obtained from the treatment T6 (22.38 ± 0.90 c g) of short duration variety (Figure 4). However, the long duration rice variety has obtained as higher weight of 1000 grains compare with the short duration rice variety. There was no significant effect ($P<0.05$) among the different irrigation intervals in respect of weight of 1000-grains in long duration variety. But there was significant difference between irrigation intervals in long duration rice variety. Interaction effect between long and short duration rice varieties and different irrigation intervals was found non-significant in respect of weight of 1000-grains.This result was indicated that the variation of 1000-grains weight among short and long duration varieties might be due to genetic constituents. Huang*et al* (2010) suggested that rice 1000-grain weight is mainly affected by the hull size that is genetically controlled.

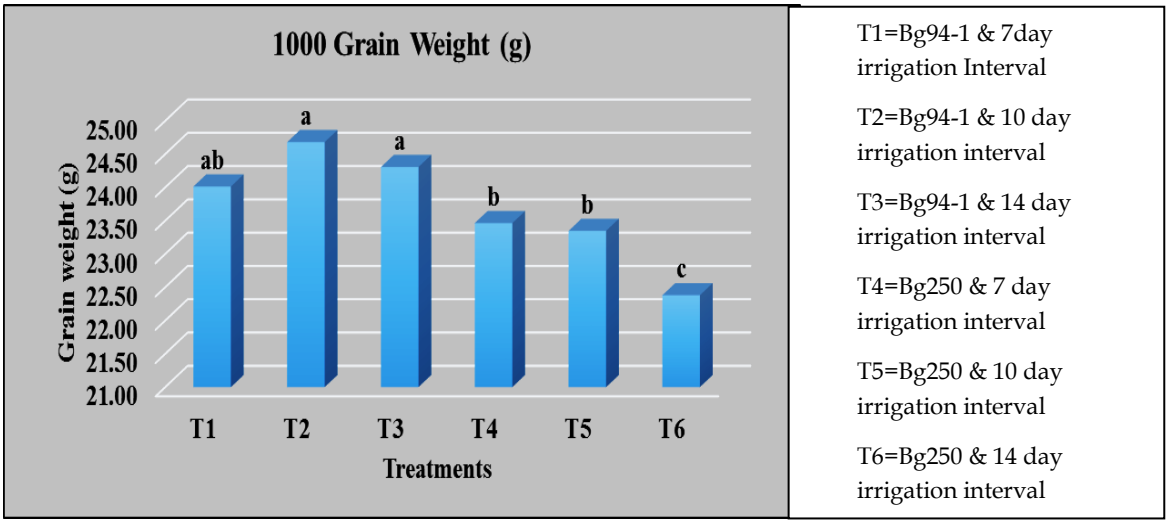


**Figure 4: Weight of 1000-grains (g) of the treatment**

**Fresh biomass weight (g)**

There was no significant difference (P<0.05) on the biomass weight (g) among the treatments. The treatment T6 was obtained highest biomass weight (30.267 ± 5.27 a g) and treatment T4 was obtained lower biomass weight (15.03 ± 4.18 g) (Figure 5). The biomass production of the short and long duration rice varieties were influenced by the genetic character.

The different treatment components was obtained not the same weight of the biomass as follows treatments T6>T3>T1=T2=T5>T4 (Figure 5). There was no significant different (P<0.05) on the biomass production with the application of different irrigation intervals in long duration rice variety. However T6 treatment of 14 day irrigation interval is significantly different from other treatments except in the same irrigation interval treatment T3 of long duration variety. This result indicated that all the treatments were obtained lower biomass production except the treatment T6.

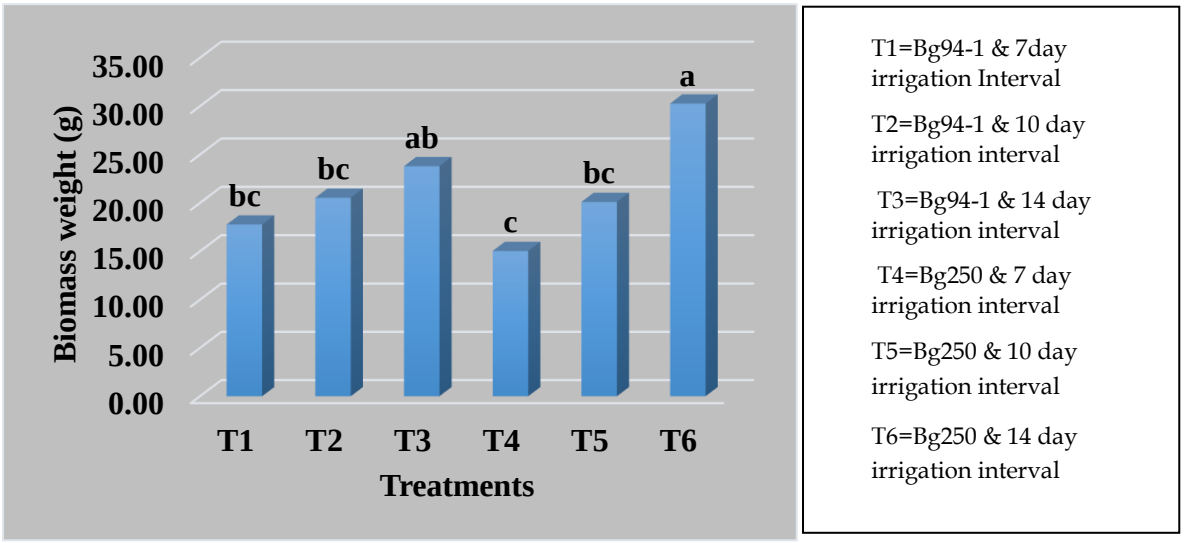


**Figure 5: Average biomass weight (g) of the treatments**

**Grain Yield (kg/ha)**

There was significant different (P<0.05) between the treatment on the grain yield. The treatment T4 with short term variety (2967.3 ± 90.92 kg/ha) was obtained highest grain yield and the treatment T3 with long term variety (1596.4 ± 220.46kg/ha) was obtained lowest grain yield (Figure 6). Grain yield was significantly (P<0.05) influenced by the varieties. The short duration rice variety was given 46.20 % higher yield than the long duration rice variety. The short and long duration rice varieties required different duration for their completion of growth phases, therefore the short duration rice variety was able to completed its growth period faster with escaping the moisture stress period but the long duration rice variety was unable to get away the moisture stress period resulted with longer irrigation interval. This was stated as drought escape refers to the ability of the plant to complete its life cycle during the period of sufficient water supply before the onset of water deficit period (Boyer, 1996). This implies a rapid germination and seedling establishment, early flowering, and maturity. Early crop establishment, for example, is related with water use efficiency and stomata conductance inhibition (Bhatia *et al*., 2014).

Matching water availability with crop needs under tropical or subtropical environments to facilitate the completion of plant phenological stages before the onset of drought is of crucial importance. Fukai (1998) through field experiments and modeling approaches showed that the rainfed rice was benefited via appropriate seeding date and/or earliness of cultivars. The yield improvement in the rice varieties is associated with an increase in higher harvest index (Damodaran, 2001). The decrease of rice yield and plant morphology with increasing water stress was also observed by WAN (2009). Seven day and ten day irrigation intervals were influenced on the higher grain yield and 14 day irrigation interval influenced on the lower yield because the plants were unable to cope up the moisture stress for 14 days during the tillering, grain filling and maturity periods. The highest grain yield was obtained with the application of 7 day irrigation interval with the short duration rice variety (2967.3 ±90.92 kg/ha) and followed by 10 day irrigation interval with the short duration rice variety (2589.50 ± 350.83 kg/ha). Interaction between varieties and the different period of irrigation intervals played an important role for promoting the rice grain yield. Grain yield was influenced by the interaction effect of varieties and the irrigation intervals. Among the treatments, the highest grain yield was observed in the combination of short duration rice variety and the 7 day irrigation interval. This was stated in other experiment that the reduction in grain yield was more related to the duration of moisture stress than to the stages of plant growth at which moisture stress occurred (De Datta & Williams, 1968).

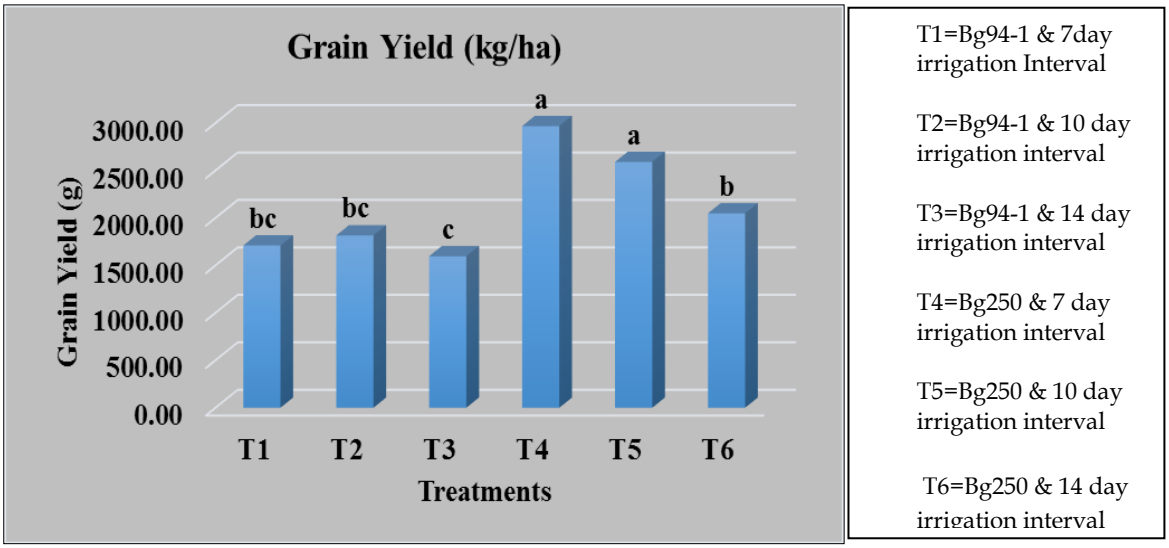


**Figure 6: Average Grain Yield (kg/ha) of the treatments**

**Days to Maturity**

There was no significant different (P<0.05) among the treatments T1, T2 and T3 then similarly in the treatments T4, T5 and T6 (Figure 7). Maturity period among the two rice varieties were significantly different (P<0.05). According to the genetic characteristics, the maturity period was vary for those two rice varieties. The long duration rice variety was cultivated under the treatment T1 (103.33 ± 0.58 a days), T2 (102.67 ± 0.58 a days) and the treatment T3 (103.33 ± 0.58 a days). The short duration rice variety was cultivated under the treatment T4 (80.00 ± 1.00 b days), T5 (81.00 ± 1.00 b days) and T6 (80.00 ± 1.00 b days) (Figure 7). The different period of irrigation intervals were not significantly affect the maturity period of these two rice varieties. But, treatment T2 (102.67 ± 0.58 a days) was

recorded as lower maturity period than other two treatments T1 and T3. The treatments T4 and T6 (80.00 ± 1.00 b days) were recorded as lower maturity period than T5. Interaction effect on days to maturity was not significant difference among the rice varieties.

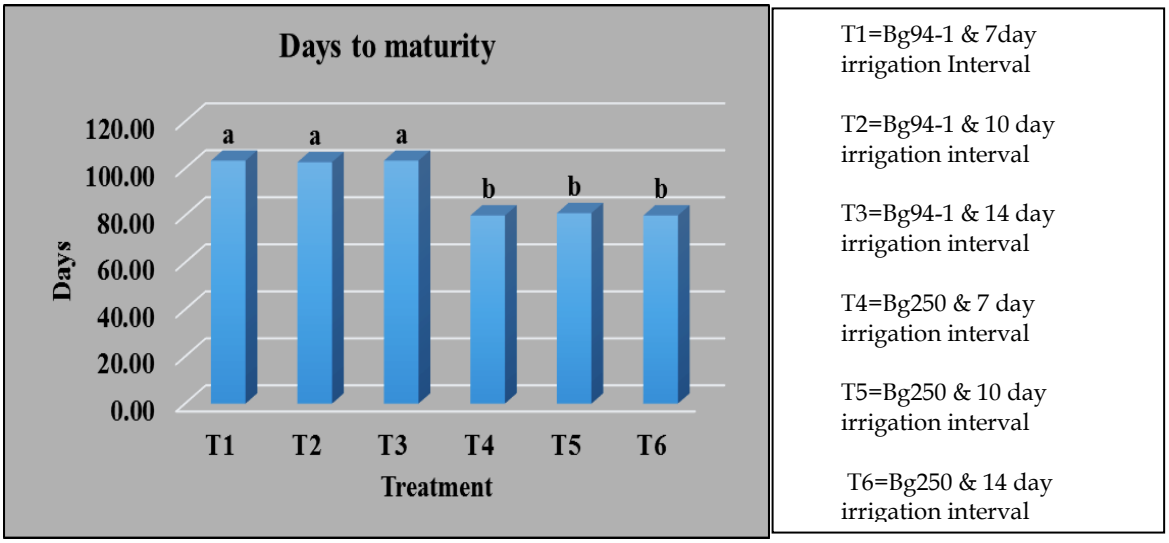


**Figure 7: Days to maturity of the treatments**

### Harvest Index

The maximum harvest index (0.3433 ± 0.0252) was obtained in the treatment T4 (short term variety and 7 days of irrigation interval) and the minimum harvest index (0.3033 ± 0.0231) was obtained in the treatment T6 (short term variety and 14 days irrigation interval).The varieties and irrigation interval were not significantly ($P<0.05$) influenced on the harvest index. Interaction effect between varieties and the irrigation intervals was not significant ($P<0.05$) in respect of harvest index.

According to the result of the study, to improve harvest index need to increase the yield. In general, harvest index is highly correlated with grain yield, which in turn is mainly related to spikelet fertility. This was stated in a study that in many situations, harvest index is closely associated with grain yield in wheat (*Triticum aestivum* L.) and rice (Yang & Zhang, 2006; Zhang & Yang, 2008; Yang *et al*., 2002).

## 3.3 Irrigation parameter

### Cost of irrigation

There was significant different ($P<0.05$) between the treatments (Figure 8). In order to assess the value of water using for the paddy farming, the labour cost were calculated as cost irrigation per hectare for both rice varieties. The time of each irrigation interval was calculated as labour cost which was Rs. 1200.00/ha. The treatment T1 was obtained highest cost for the irrigation (Rs. 12000/ha.) and the treatment T6 was obtained lowest cost for the irrigation (Rs. 3600/ha). According to the maturity period of short and long duration rice varieties the times of irrigation application vary. When the irrigation interval is longer the cost of irrigation is less irrespective of short or long duration variety.

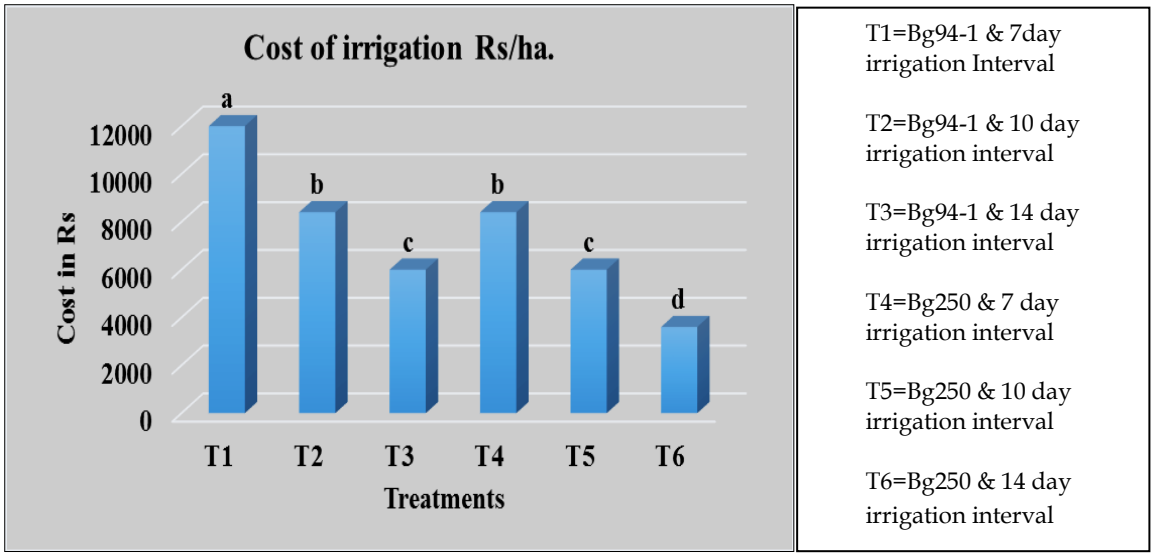


**Figure 8: Irrigation cost per acre in rupees for different treatments**

**Net Profit**

In the calculation of net profit cost of inputs are not considered as it was same for all treatment. But only irrigation cost is considered as it is different for treatments. Based on this analysis, the treatment T4 was obtained higher yield, gross income and net profit followed by treatment T5 and then followed by treatment T6 (Table 2).The treatment T1 was obtained lowest gross income and net profit followed by T3 and then T2 treatments. The long duration rice variety was cultivated under the treatment T1, T2 and T3 which were obtained lower income compare with short duration rice variety which was cultivated under the treatment T4, T5 and T6. The highest gross income was obtained in treatment T4 was 50.4% higher than the gross income of treatment T1. The different irrigation intervals were significantly different ($P<0.05$) on the cost of irrigation.

**Table 2: Cost of irrigation and net profit analysis**

| Treatment | Total Grain Yield Kg/ha. | Cost of irrigation/ ha. Rs. | Gross Income/ ha. Rs. | Net Profit (Gross Income (-) Irrigation Cost / ha. Rs.) |
|---|---|---|---|---|
| T1 | 1709.8 bc | 12,000.00 | 56,423.40 | 44,423.40 |
| T2 | 1816.0 bc | 8,400.00 | 59,928.00 | 51,528.00 |
| T3 | 1596.4 c | 6,000.00 | 52,681.20 | 46,681.20 |
| T4 | 2967.3 a | 8,400.00 | 97,920.90 | 89,520.90 |
| T5 | 2589.5 a | 6,000.00 | 85,453.50 | 79,453.50 |
| T6 | 2048.8 b | 3,600.00 | 67,610.40 | 64,010.40 |

*1 Kg of paddy = Rs 33.00, the current price was taken in Ampara district.

The results of the study states that the 7 day irrigation interval with short duration rice variety was found economically highest profit than other treatment combinations of irrigation intervals with rice varieties. This was states same in the research of Nalley *et al*.

(2015) as investigated the economic viability of different treatments and found the lowest profit in the treatment with highest water productivity.

## 4 CONCLUSIONS AND RECOMMENDATIONS

The experiment was conducted to find out the effects of different period of irrigation intervals on growth and the yield of the selected rice varieties Bg 94-1 (Long duration rice variety) and Bg 250 (Short duration rice variety) as a solution for water scarcity during *Yala* season in Ampara district. The irrigation interval of once in 7 days with short duration rice variety Bg 250 was produced 27% of greater yield than the yield of same irrigation interval applied with the rice variety Bg 94-1.And also, the cost of irrigation for short duration rice variety was lower compared to the long duration rice variety which was required drastically higher cost for the irrigation.

Irrigation interval of once in 10 days has potential to save water and increase water productivity without any significant negative impacts on the grain yield in rice variety Bg 250. Rice cultivation of short duration rice varieties (80 days) with the application of Irrigation intervals 7 day and 10dayscan be used as an act of adaptation to limited water availability. Therefore farmers in Ampara District can confidently select the short duration variety for cultivation during Yala season with the irrigation interval of 7 and 10 days interval. Even though the experiment was done in pots similar results could be expected in field if the farmers are convinced with the findings of this research study.

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