EFFECT OF DIFFERENT WATER REGIMES ON YIELD OF RED ONION (*Allium cepa*), LEAF RELATIVE WATER CONTENT, GRAVIMETRIC SOIL MOISTURE CONTENT AND WATER USE EFFICIENCY UNDER NON-CALCIC BROWN SOILS (*Haplustalf*) IN THE LOW COUNTRY DRY ZONE OF SRI LANKA

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ABSTRACT

Effect of six water regimes based on irrigation water/cumulative pan evaporation (IW/CPE) ratio (0.25, 0.50, 0.75, 1.00, 1.25 and 1.5) with presence or absence of straw mulch and compost on yield of red onion (*Allium cepa* L.), water use efficiency, gravimetric soil moisture content and leaf relative water content was evaluated in two consecutive *yala* seasons in year 2010 and 2011 at Regional Agricultural Research and Development Centre, Aralaganwila using split-split plot design with three replicates. Irrigation water was applied daily based on the pan evaporation data and crop coefficient (Kc) for onion relevant to different growth stages. Gravimetric soil moisture content and Leaf relative water content was measured just before irrigation at 3, 6 and 9 weeks after planting. Results revealed that, highest yield and yield components of onion were observed under highest water regime (IW/CPE ratio 1.5) in both seasons. Highest gravimetric soil moisture content and leaf relative water content was also recorded by IW/CPE ratio of 1.5.Although, highest water use efficiency in 2010 *yala* season was recorded in IW/CPE ratio of 1.5, in year 2011 *yala* season it was under lowest water regime (IW/CPE ratio 0.25). In sub plot and sub-sub plot treatments, application of straw mulch and compost recorded the highest yield attributes of onion, gravimetric

soil moisture content, leaf relative water content and water use efficiency of onion in both seasons. Based on the results, it was concluded that application of straw mulch and compost have increasing effect on red onion yield,leaf relative water content, gravimetric soil moisture content and water use efficiency. However, since highest red onion bulb yield, yield components, soil and plant moisture status were recorded in highest soil moisture regime (1.5 IW/CPE ratio) tested, further studies are needed to find out the optimum water regime to achieve maximum crop yield and water use efficiency in sandy non-calcic brown soil in the dry zone of Sri Lanka.

Keywords: Irrigation, IW/CPE ratio, mulch, compost, red onion, water use efficiency

INTRODUCTION

The Sri Lankan Government has decided to utilize 35% of paddy lands during 2014 *yala* season for the cultivation of supplementary food crops such as big onions, red onions, potatoes, chilies, maize, green gram, soya bean, cowpea etc. The main objective is to achieve self- sufficiency in supplementary food crops and save foreign exchange spent on imports. Among these supplementary food crops, Onion (*Allium cepa* L.) is one of the most important vegetable, cash, spice and condiment crop cultivated all over the world on commercial scale. In Sri Lanka, total production of red onion in year 2014 was 46,034 Mt in an extent of 9,661 ha. However, Sri Lanka imported 11,839 Mt of red onion in year 2014 spending considerable amount of foreign exchange.

Onion consumption is elastic with respect to income, increasing 1.4 percent for each 1 percent rise in real per capita GNP (Pattie and Wickramasinghe, 1993). Therefore, continuous increase of demand for red onion can be expected with increasing income levels of Sri Lankans. Therefore, there is a need to increase the production to achieve self-sufficiency in onion. To achieve the target, possibility of using non-traditional areas for onion cultivation need to be explored.

However, in irrigation water management point of view, shortage of water still remains one of the major limiting factors for agricultural production even in major irrigation schemes.With the completion of the multiphase diversion projects and other major irrigation schemes, the phase of expansion in the country's irrigated area have become limited (IIMI, 1992). The emphasis now is on increasing water use efficiency of the existing irrigation systems and on-farm water management for higher productivity. Hence, present study was conducted to identify appropriate irrigation water regime in terms of yield, yield attributes of red onion and water use efficiency with and without application of straw mulch and compost.

MATERIALS AND METHODS

The area where the experiment was conducted has a unimodal rainfall pattern with average annual rainfall of about 1100 mm. Soil of the area is moderately deep, well drained, Non Calcic Brown soils (*Haplustalfs*) (Panabokke, 1996). The total rainfall received during *yala* 2010 and 2011 was 334.5 mm and 113 mm respectively.

The experimental field was ploughed once with a tractor and made it to a fine tilt using a harrow. Main plots were prepared in a dimension of 4 x 1m. The dimensions of sub and sub-sub plots were 2 x 1m and 1 x 1m respectively. Irrigation water was applied daily to each treatment plot based on respective IW/ CPE ratio corresponding to the growth stage-specific crop coefficient (Kc) using a bucket. IW was determined using the amount of pan evaporation in previous day and converting it to a water volume. Rice straw mulch (10t/ha) and compost (10t/ha) were applied to the respective plots at the beginning of the experiment. Red onion (cv. Vethalam) was planted at the spacing of 10 x 10 cm in the same day in each plot. A same quantity of irrigation with a depth of 4cm was given to each plot just after transplanting and the subsequent irrigations were adopted on the basis of different IW/CPE ratio designated to each plot. Chemical fertilizer application to onion crop and other crop management practices were adopted as the recommendation of the Department of Agriculture (DOA, 1990). Experiment was conducted without application of organic manure, except for the plots designated to be with compost application.

The water table depth of the experiment site was below 2 m throughout the experimentation. Hence, the contribution of ground water was considered to be negligible. However, to prevent the lateral movement of water, polythene sleeves were inserted to the soil up to one meter depth around the main plots.

MEASUREMENTS

Rainfall and Evapotranspiration rate

Daily rainfall amount and evapotranspiration rate were measured using recording type rain-gauge and class A evaporation pan installed in the research centre respectively. Irrigation water was applied based on daily evapotranspiration rate and crop coefficient (Kc) relevant to different growth stages as follows; initial stage, 25 days (0.5), Growth stage, 40 days (0.7), mid stage, 20 days (1.8) and maturity stage, 10 days (1.0) (FAO, 1992). Precipitation occurred in the 24-hour period of previous day was taken into account in calculating the evapotranspiration. Whenever precipitation was greater than evaporation, measured increments of water was dipped from the pan. Application of irrigation water was withheld whenever the daily rainfall exceeds the cumulative pan evaporation.

Leaf Relative Water Content

The leaf relative water content was determined in the fully expanded topmost leaf of the main shoot at 3 weeks interval. The sampling was practiced just before the irrigation. The fresh weight of the sample leaves was recorded and the leaves were immersed in distilled water in a Petri dish. After 2 hours, the leaves were removed, the surface water was blotted-off and the turgid weight was recorded. Samples were then dried in an oven at 70°C to constant weight. Leaf relative water content was calculated using the following formula (Turner, 1981):

$$LRWC\ (\%) = [(F.W - D.W) / (T.W - D.W)] \times 100 \qquad \text{eq. (1)}$$

Where: LRWC (%) = Leaf relative water content, FW = fresh weight leaves, DW = dry weight leaves, TW = Turgid weight

Gravimetric soil moisture content

Composite soil samples were collected up to 20cm depth in soil in each plot at 3 weeks interval to determine the gravimetric soil moisture content. Soil samples were collected just before the irrigation.Fresh weight of the samples were recorded just after the sampling and oven dry weight of the soil was recorded by placing soil samples at 1050C in an oven to a constant weight.

Yield and yield components

Ten tagged representative plants were harvested from each plot for recording yield attributes of onion. Harvest was done at the time when more than 80% of the leaves (pseudo-stems) were bent over. Bulbs per cluster, average bulb size (g/bulb), plants/m^2 and plot yields were determined at the time of harvesting.

Water use efficiency (WUE)

The water use efficiency, as kg of onion bulb yield per cubic meter of water used was calculated by dividing the bulb yield of red onion with total water used as irrigation and rainfall.

RESULTS AND DISCUSSION

Yield and yield components

Among the different water regimes tested, IW/CPE ratio 1.5 (M6) recorded the significantly highest number of bulbs per plant, weight of one bulb and bulb yield during both the years (Table 1).This may be attributed to greater cell elongation and turgidity owing to adequate moisture availability in the soil. Sharma *et al.* (1994) and Mishra *et al.* (1996) also reported higher growth and yield parameters with irrigation at 1.5 IW/CPE ratio. The lowest yield parameters were recorded with irrigation at 0.25 IW/CPE ratio. Moisture stress in lower moisture regimes might have adversely affected the cell division and cell enlargement because of reduction in the level of endogenous phytohormones viz., auxins (Davenport *et al.*, 1980 and Nandi *et al.*, 2002).These results may also be due to the negative effect of soil moisture deficits on vegetative growth and dry matter accumulation in reproductive stage (bulb formation). The results are also in harmony with those of Encisoet *al.* (2009) and Pejiet al (2011), who found that irrigation has highly affected the total onion yield, yield components and morphological characteristics of onion bulbs. Moreover, under the Egyptian conditions, Morsy and Abd El- Latif (2012) also recorded similar trends.

Onion needs frequent irrigation (Sen *et al.*, 2006). Although, many researchers reported highest bulb yield around 1 to 1.2 IW/CPE ratio[Singh and Sharma (1991); Hegde (1986) andPalled *et al.* (1988)], present study revealed much higher water requirement for achieving maximum crop yield under sandy non-calcic brown soils in the dry zone of Sri Lanka. Although, the lateral movement of water was prevented, high rate of percolation and evapotranspiration might have reduced the required water availability to the onion plants at lower IW/CPE ratio. Sen *et al.* (2006) also observed continuous significant increase of onion bulb yield of onion up to 1.5 IW/CPE ratio, which is the highest IW/CPE ratio tested. Similar results were observed by Aujla and Madan (1992), who found that higher ratio of IW/CPE ranging from 1.25 to 1.5 produced the higher red onion yield than lower ratios of 0.75 to 1.0. Sadaria*et al.* (1997) also reported that irrigation at 1.4 IW/CPE ratio gave the highest bulb yield of onion. However, there was no significant difference of bulb yield among the IW/CPE ratio of 0.75, 1 and 1.25.

Application of mulch and compost significantly increased the red onion yield and yield components in both seasons. Shock *et al.* (1999) reported that with straw mulch, onion yield was increased by 64%. It was also reported that the yield increase were mainly due to the decrease of water runoff and increase of movement of water in the soil profile in rooting depth. Adetunji (1994) reported in semi-arid Nigeria, onion that was mulched during dry season increased bulb yield by 80%. Farmers normally do not practice mulching in onions as it might host the plant pathogenic fungi. However, in both seasons of present experiment, any significant pest or disease attack to onion was not observed. Significant interaction between different water regimes and application of mulch on yield and yield components of red onion was not observed. Application of compost (10t/ ha) also significantly increased the crop yield and yield components (except bulbs per cluster) of red onion in both seasons. Application of compost might have increased the water holding capacity of the soil and added micro and macro nutrients to the soil than the chemical fertilizer alone treated plots. Higher gravimetric soil moisture contents of soil (Table 4) and higher leaf relative water content (Table 3) under compost application is also an indication of these effects.There was also no significant interaction between different water regimes and application of compost on crop yield and yield components except weight of one bulb.

Table 1. Effect of different IW/CPE ratio, mulching and compost application on bulbs per plant, weight of one bulb and bulb yield of Red onion

Treatments	Bulbs per plant		Weight of one bulb (g)		Bulb yield (t/ha)	
	2010	2011	2010	2011	2010	2011
Main treatments (IW/CPE ratio)						
M1. IW/CPE 0.25	5.25f	6.18e	0.348d	0.41d	4.55d	5.01e
M2. IW/CPE 0.5	6.10e	6.37e	0.563cd	0.62cd	5.43d	5.83de
M3. IW/CPE 0.75	6.73d	7.12d	1.000c	0.93c	7.33bc	6.92cd
M4. IW/CPE 1.0	7.23c	7.77c	1.418bc	1.53b	8.098b	8.12bc
M5. IW/CPE 1.25	7.71b	8.22b	1.663b	1.93b	9.479b	9.88b
M6. IW/CPE 1.5	8.40a	9.10a	2.701a	3.54a	12.196a	13.37a
S.Ed.±	0.16	0.18	0.199	0.21	0.78	0.81
CD (p = 0.05)	0.35	0.39	0.443	0.45	1.73	1.79
Sub treatments (Presence or absence of 10/ha of mulch)						
S1. With mulch	7.089a	7.74a	1.551a	1.80a	9.078a	9.10a
S2. Without mulch	6.725b	7.18b	1.025b	1.18b	6.619b	7.94b
S.Ed.±	0.116	0.12	0.206	0.21	0.32	0.37
CD (p = 0.05)	0.253	0.41	0.450	0.46	0.71	0.82
Sub-sub treatments (Presence or absence of 10t/ha of compost)						
SS1. With compost	7.053	7.64	1.313a	1.77a	8.506a	9.78a
SS2. Without compost	6.761	7.28	1.183b	1.22b	7.191b	7.26b
S.Ed.±	0.154	0.157	0.138	0.141	0.32	0.37
CD (p = 0.05)	NS	NS	0.195	0.199	0.71	0.82

Table 1. Cont..

Interaction (MxS)						
S.Ed.±	0.285	0.288	0.506	0.512	0.79	0.81
CD (p = 0.05)	NS	NS	NS	NS	NS	NS
Interaction (MxSS)						
S.Ed.±	0.377	0.379	0.195	0.202	0.80	0.81
CD (p = 0.05)	NS	NS	NS	NS	NS	NS
Interaction (SxSS)						
S.Ed.±	**0.217**	**0.219**	**0.113**	**0.116**	**0.46**	**0.49**
CD (p = 0.05)	**NS**	**NS**	**0.233**	**NS**	**NS**	**NS**
Interaction (MxSxSS)						
S.Ed.±	**0.533**		**0.276**		**1.13**	
CD (p = 0.05)	**NS**		**NS**		**NS**	

Means followed by the same letter are not significantly different at 5% probability level. M=main plot effect, S=subplot effect, SS=sub-sub plot effect, CD= critical difference, S.Ed.± = standard error of deviation

Significantly highest number of Plants/m2of red onion at 9 weeks after planting was recorded by the IW/CPE ratio 1.5 followed by IW/CPE ratio of 1.25 and 1 (Table 2). High rate of plant mortality was observed under lower moisture regimes may be due to the insufficient water availability for normal crop growth. However, significant mulch effect or compost effect on number of Plants/m2 was not observed. There was a significant interaction between application of mulch and compost on number of Plants/m2. This is mainly due to the higher number of plants under non-mulch treatment over mulched treatment only in compost applied plots (Interaction table not shown). Compost application might have induced more plants per cluster but may have smothered by application of mulch. However, according to onion bulb yield (Table 1); this smothering seems to have no significant effect on final bulb yield.

Table 2. Effect of different IW/CPE ratio, mulching and compost application on plant count of Red onion at 9 weeks after planting

Treatments	**Plants/m^2**	
	2010	**2011**
Main treatments (IW/CPE ratio)		
M1. IW/CPE 0.25	320.7e	344d
M2. IW/CPE 0.5	404.7d	412d
M3. IW/CPE 0.75	465.9c	501c
M4. IW/CPE 1.0	553.5b	588b
M5. IW/CPE 1.25	581.0b	613ab
M6. IW/CPE 1.5	647.5a	659a
S.Ed.±	**25.0**	**27.6**
CD (p = 0.05)	**55.6**	**61.4**
Sub treatments (Presence or absence of 10/ha of mulch)		
S_1. With mulch	503.1	544
S_2. Without mulch	488.02	495
S.Ed.±	**14.5**	**18.54**
CD (p = 0.05)	**NS**	**NS**
Sub-sub treatments (Presence or absence of 10t/ha of compost)		
SS1. With compost	503.4	555
SS2. Without compost	487.7	484
S.Ed.±	**12.75**	**17.20**

Table 2:-Cont..

CD (p = 0.05)	**NS**	**NS**
Interaction (MxS)		
S.Ed.±	**35.7**	**39.5**
CD (p = 0.05)	**NS**	**NS**
Interaction (MxSS)		
S.Ed.±	**31.2**	**33.4**
CD (p = 0.05)	**NS**	**NS**
Interaction (SxSS)		
S.Ed.±	**18.03**	**22.6**
CD (p = 0.05)	**37.22**	**46.65**
Interaction (MxSxSS)		
S.Ed.±	**44.17**	**48.4**
CD (p = 0.05)	**NS**	**NS**

Means followed by the same letter are not significantly different at 5% probability level. M=main plot effect, S=subplot effect, SS=sub-sub plot effect, CD= critical difference, S.Ed.± = standard error of deviation

Leaf relative water content

Among the different water regimes tested, IW/CPE ratio of 1.5 recorded the highest leaf relative water content at 3, 6, and 9 weeks after planting in both the years (Table 3). There was a significant difference of leaf relative water content among different water regimes except IW/CPE ratio of 1 and 1.5 in year 2010 that recorded non-significant Leaf Relative Water Content values. Lowest Leaf Relative Water Content was recorded in IW/CPE ratio of 0.25. Higher water availability in soil profile (Table 4) under IW/CPE ratio 1.5 than the rest of the irrigation treatments may be the reason for higher leaf relative water content under IW/CPE ratio 1.5. Application of mulch and compost also increased the leaf relative water content in both the years. Reduction of water evaporation from soil under mulched treatments and higher water holding capacity of soil under compost application may be the reason for higher leaf relative water content in mulched and compost applied treatments. There was a significant interaction exist between water regimes and application of mulch in both years, except 6 weeks after planting, where interaction was not significant (Interaction table not shown). Leaf Relative Water contentvaries in wider range (42.1 to 92.7 at 3 weeks after planting and 49.4 to 76.7 at 9 weeks after planting in year 2010) in mulched treatment than the non-mulched treatment (38.2 to 79.5 at 6 weeks after planting and 48.4 to 64.6 at 9 weeks after planting in year 2010). This may be due to the soil water conservation ability of mulched treatments than non-mulched treatment even under low IW/CPE ratios (Table 4) that might have increased the water availability to the plants in mulched treatment.There was also a significant interaction exists between application of mulch and compost on leaf relative water content.Under the application of compost, there was a wide range of leaf relative water content (53.8 to 63. 0 at 3 weeks after planting and 56.4 to 64.8 at 6 weeks after planting). However, without application of compost, leaf relative water content was varied in a narrow range (56.2 to 60.6 at 3 weeks after planting and 54.86 to 58.7 at 6 weeks after planting). This clearly indicated the combined effect of mulching and compost application on leaf relative water content. Significantly higher gravimetric soil moisture content in mulched and compost applied plots is also aproof to this assumption. Decrease in RWC in plants under drought stress may depend on plant vigor reduction and have been observed in many plants (Liu *et al.*, 2002). Under water deficit, cell membrane subjects to changes such as penetrability and decrease in sustainability (Blokina *et al.*, 2003). Generally, it seems that osmoregulation is one of the main mechanisms preserving turger pressure in most plant species against water loss. It causes plant to continue water absorption and retain metabolic activities (Gunasekera and Berkowiz, 1992).

Table 3. Effect of different IW/CPE ratio, mulching and compost application on Leaf Relative Water Content of Red Onion

Treatments	Leaf Relative Water Content (3WAP)		Leaf Relative Water Content (6WAP)		Leaf Relative Water Content (9WAP)	
	2010	2011	2010	2011	2010	2011
Main treatments (IW/CPE ratio)						
M_1. IW/CPE 0.25	40.20f	43.81f	43.48e	45.96e	46.22f	48.25e
M_2. IW/CPE 0.5	46.64e	51.11e	51.70d	50.81d	51.35e	54.31d
M_3. IW/CPE 0.75	54.91d	58.43d	54.10d	56.11c	57.30d	62.61c
M_4. IW/CPE 1.0	59.77c	64.21c	58.98c	60.31b	60.96c	64.54c
M_5. IW/CPE 1.25	70.33b	69.86b	64.64b	63.21b	65.85b	71.31b
M_6. IW/CPE 1.5	86.11a	81.52a	71.06a	77.11a	70.67a	73.83a
S.Ed.±	**1.95**	**2.02**	**1.43**	**1.47**	**1.21**	**1.25**
CD (p = 0.05)	**4.35**	**4.50**	**3.20**	**3.28**	**2.69**	**2.77**
Sub treatments (Presence or absence of 10/ha of mulch)						
S_1. With mulch	63.71a	64.67a	60.73a	61.66a	61.80a	67.47a
S_2. Without mulch	55.62b	58.31b	53.92b	56.19b	55.65b	57.37b
S.Ed.±	**0.35**	**0.38**	**2.33**	**2.41**	**0.54**	**0.61**
CD (p = 0.05)	**0.76**	**0.82**	**5.09**	**5.25**	**1.18**	**1.33**
Sub-sub treatments (Presence or absence of 10t/ha of compost)						
SS1. With compost	62.05a	62.32a	58.47a	60.71a	60.64a	65.52a
SS2. Without compost	57.27b	60.66b	56.18b	57.11b	56.82b	59.42b
S.Ed.±	**0.56**	**0.58**	**1.05**	**1.11**	**0.33**	**0.39**
CD (p = 0.05)	**1.17**	**1.21**	**2.16**	**2.28**	**0.68**	**0.80**

Table 3. Cont..

Interaction (MxS)						
S.Ed.±	**0.85**	**0.91**	**5.72**	**5.77**	**1.32**	**1.34**
CD (p = 0.05)	**1.87**	**2.00**	**NS**	**NS**	**2.89**	**2.93**
Interaction (MxSS)						
S.Ed.±	**1.39**	**1.42**	**2.57**	**2.61**	**0.81**	**0.83**
CD (p = 0.05)	**2.87**	**2.93**	**5.31**	**5.39**	**1.68**	**1.72**
Interaction (S x SS)						
S.Ed.±	**0.80**	**0.85**	**1.48**	**1.51**	**0.47**	**0.51**
CD (p = 0.05)	**1.66**	**1.76**	**3.06**	**NS**	**0.97**	**1.05**
Interaction (M x S x SS)						
S.Ed.±	**1.97**	**0.21**	**3.63**	**3.66**	**1.15**	**1.17**
CD (p = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Means followed by the same letter are not significantly different at 5% probability level. M=main plot effect, S=subplot effect, SS=sub-sub plot effect, CD= critical difference, S.Ed.± = standard error of deviation

Gravimetric soil moisture content

Significantly highest gravimetric soil moisture content at 3, 6 and 9 weeks after planting in both 2010 and 2011 years was recorded by the IW/CPE ratio of 1.5 (Table 4). However, it was on par with IW/CPE ratio of 1.25 except 9th week after planting in year 2010. The differences of gravimetric soil moisture content among different IW/CPE ratio is marginal compared with differences of leaf relative water content (Table 3). It is not clear whether there was any resistance of further soil moisture depletion after reaching certain level of soil moisture depletion. However, there was a significant increase of gravimetric soil moisture content at 3, 6 and 9 weeks after planting under mulch and compost application in both the years.Compost might have improved organic matter status and total porosity of the soil (Adeyemo and Agele, 2010). This might have favorably impacted soil water holding capacity and modify rainfall infiltration. Khurshid *et al.* (2006) also stated the same results that mulching and organic manure application improves the ecological environment of the soil and increases soil water contents.

Table 4. Effect of different IW/CPE ratio, mulching and compost application on gravimetric soil moisture content

Treatments	Soil moisture % at 3weeks after planting		Soil moisture % at 6 weeks after planting		Soil moisture % at 9 weeks after planting	
2010	**2011**	**2010**	**2011**	**2010**	**2011**	
Main treatments (IW/CPE ratio)						
M1. IW/CPE 0.25	5.59d	6.53c	8.10d	7.44d	17.21bc	5.76c
M2. IW/CPE 0.5	8.08cd	7.55c	11.35c	10.99c	15.73c	7.59b
M3. IW/CPE 0.75	9.37c	11.56b	12.27bc	12.57bc	17.16bc	8.44b
M4. IW/CPE 1.0	10.87bc	10.79b	13.55bc	14.02b	17.86b	9.14b
M5. IW/CPE 1.25	13.07ab	12.87ab	14.29ab	14.69ab	18.11b	10.82ab
M6. IW/CPE 1.5	14.43a	14.22a	15.60a	16.52a	19.95a	11.66a
S.Ed.±	**1.45**	**1.51**	**1.07**	**1.12**	**0.82**	**0.76**
CD (p = 0.05)	**3.24**	**3.37**	**2.38**	**2.49**	**1.82**	**1.69**
Sub treatments (Presence or absence of 10/ha of straw mulch)						
S1. With mulch	11.70a	12.54a	14.61a	15.83a	20.08a	10.54a
S2. Without mulch	8.77b	8.62b	10.45b	9.58b	15.26b	7.26b
S.Ed.±	**0.53**	**0.57**	**0.32**	**0.33**	**0.20**	**0.19**
CD (p = 0.05)	**1.15**	**1.24**	**0.70**	**0.72**	**0.44**	**0.42**
Sub-sub treatments (Presence or absence of 10 t/ha of compost)						
SS1. With compost	11.04a	11.11a	13.96a	14.84a	19.30a	9.81a
SS2. Without compost	9.43b	10.05b	11.10b	10.57b	16.04b	7.99b
S.Ed.±	**0.44**	**0.45**	**0.30**	**0.32**	**0.25**	**0.22**
CD (p = 0.05)	**0.91**	**0.93**	**0.62**	**0.66**	**0.53**	**0.47**

Table 4. Cont..

Interaction (MxS)						
S.Ed.±	**1.30**	**1.33**	**0.79**	**0.81**	**0.50**	**0.53**
CD (p = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Interaction (MxSS)						
S.Ed.±	**1.08**	**1.09**	**0.73**	**0.76**	**0.63**	**0.65**
CD (p = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Interaction (SxSS)						
S.Ed.±	**0.62**	**0.66**	**0.42**	**0.45**	**0.36**	**0.37**
CD (p = 0.05)	**NS**	**NS**	**0.88**	**NS**	**0.75**	**NS**
Interaction (MxSxSS)						
S.Ed.±	**1.53**	**1.57**	**1.04**	**1.08**	**0.89**	**0.91**
CD (p = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Means followed by the same letter are not significantly different at 5% probability level. M=main plot effect, S=subplot effect, SS=sub-sub plot effect, CD= critical difference, S.Ed.± = standard error of deviation

Water use efficiency

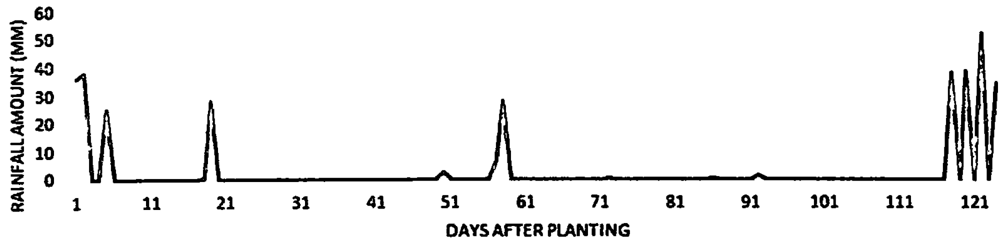

Figure 1. Rainfall received during crop growing period of onion in 2010 *yala* season

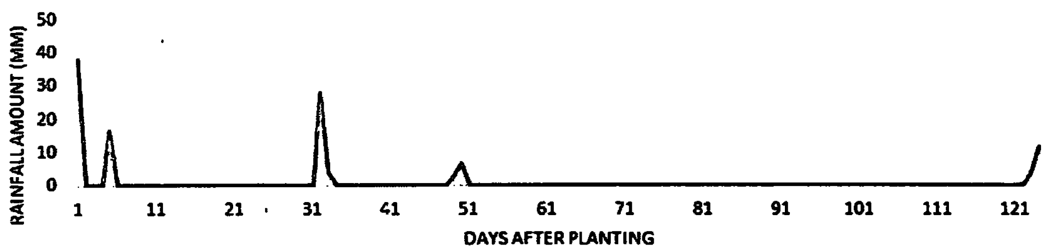

Figure 2. Rainfall received during crop growing period of onion in 2011 *yala* season

In year 2010 *yala* season received 334.5mm of rainfall (Figure 1) compared to 113.0 mm in 2011 *yala* season (Figure 2). Generally, water use efficiency in 2010 *yala* season was lower than year 2011 (Table 5 and 6). In year 2010, when effective rainfall was higher, significantly highest water use efficiency was recorded in highest water regime (IW/CPE ratio 1.5). In contrast, when effective rainfall was lower, highest water use efficiency was recorded in lowest water regime (0.25 IW/CPE ratio). High intensity rainfall (exceeding 25mm/day) received in 3 days in 2010 *yala* season compared to 1 day in 2011 *yala* season might be the reason for lower WUE in 2010 *yala* season. Majority of rainfall received at the beginning of planting and crop harvesting stage in both 2010 and 2011 *yala* seasons (Figure 1 and 2). These rainfalls might have no or very little effect on onion yield. Most of the rain water received in the season might also have lost as runoff or deep percolation without contributing to the yield increase of onion but reducing the water use efficiency of the crop. Even it might have negatively affected the growth and yield of onion due to leaching of soil nutrients and cloudy weather condition. Angus (1983) also reported that water deficit stress during the vegetative phase of development, can increase WUE of crops significantly. In contrast, Bhagyawant *et al.* (2015) reported that the onion yields and field water use efficiency are higher with less water stress and reduced with increase in water stress. Results of the present study are also in accordance with these findings only in 2010 *yala* season. However, when there was relatively low amount of effective rainfall, contrasting results were observed. Although, contrasting results of water use efficiency among water regimes were observed in two seasons, there was significantly higher water use efficiency of red onion under straw mulching and compost application in both the years. Soil moisture conservation under mulch treatment and higher water holding capacity of compost application together with favorable effect of mulching and compost application on onion yield might be the reason for significantly higher water use efficiency in mulch and compost application treatments. However, in general water use efficiencyof onion in the present study was quite low compared to the water use efficiency of 4.68 kg m-3 reported by Goonasekera (1978). Observed differences of present study may possibly be due to the lower water holding capacity of non-calcic brown soil and high evaporative demand of the environment of low country dry zone. Relatively high intensity rainfall especially at the end of 2010 *yala* season also might have reduced the water use efficiency of onion crop.

Table 5. Effect of different IW/CPE ratio, mulching and compost application on water use efficiency of onion crop in 2010 *yala* season

Treatment	Irrigation water used (m^3)	Total Rainfall(m^3)	Total Water used(m^3)	Bulb yield	Water Use Efficiency ($Kg/ha/m^3$)
Main treatments (IW/CPE ratio)					
M_1. IW/CPE 0.25	1018.5	3345.0	4363.5	4550.0	1.04de
M_2. IW/CPE 0.5	2037.0	3345.0	5382.0	5430.0	1.01e
M_3. IW/CPE 0.75	3055.5	3345.0	6400.5	7330.0	1.14b
M_4. IW/CPE 1.0	4074.0	3345.0	7419.0	8098.0	1.09cd
M_5. IW/CPE 1.25	5092.5	3345.0	8437.5	9479.0	1.12bc
M_6. IW/CPE 1.5	6111.0	3345.0	9456.0	12196.0	1.28a
S.Ed.±					**0.037**
CD (p = 0.05)					**0.079**
Sub treatments (Presence or absence of 10/ha of straw mulch)					
S_1. With mulch	3564.8	3345.0	6909.8	9078	1.31a
S_2. Without mulch	3564.8	3345.0	6909.8	6619	0.96b
S.Ed.±					**0.05**
CD (p = 0.05)					**0.14**
Sub-sub treatments (Presence or absence of 10t/ha of compost)					
SS1. With compost	3564.8	3345.0	6909.8	8506	1.23a
SS2. Without compost	3564.8	3345.0	6909.8	7191	1.04b

Table 5. Cont..

S.Ed.±	**0.015**
CD (p = 0.05)	**0.040**
Interaction (MxS)	
S.Ed.±	**0.06**
CD (p = 0.05)	**NS**
Interaction (MxSS)	
S.Ed.±	**0.04**
CD (p = 0.05)	**NS**
Interaction (SxSS)	
S.Ed.±	**0.05**
CD (p = 0.05)	**NS**
Interaction (MxSxSS)	
S.Ed.±	**0.08**
CD (p = 0.05)	**NS**

Means followed by the same letter are not significantly different at 5% probability level. M=main plot effect, S=subplot effect, SS=sub-sub plot effect, CD= critical difference, S.Ed.± = standard error of deviation

Table 6. Effect of different IW/CPE ratio, mulching and compost application on water use efficiency of onion crop in 2011 *yala* season

Treatment	Irrigation water used (m3)	Total Rainfall(m3)	Total Water used(m3)	Bulb yield	Water Use Efficiency (Kg/ha/m3)
Main treatments (IW/CPE ratio)					
M_1. IW/CPE 0.25	1244.3	1130	2374.3	5010	2.11a
M_2. IW/CPE 0.5	2488.5	1130	3618.5	5830	1.61b
M_3. IW/CPE 0.75	3732.8	1130	4862.8	6920	1.42c
M_4. IW/CPE 1.0	4977.0	1130	6107.0	8120	1.32d
M_5. IW/CPE 1.25	6221.3	1130	7351.3	9880	1.34cd
M_6. IW/CPE 1.5	7465.5	1130	8595.0	13370	1.55b
S.Ed.±					**0.042**
CD (p = 0.05)					**0.090**
Sub treatments (Presence or absence of 10/ha of straw mulch)					
S_1. With mulch	4354.9	1130	5484.9	9100	1.66a
S_2. Without mulch	4354.9	1130	5484.9	7940	1.45b
S.Ed.±					**0.083**
CD (p = 0.05)					**0.178**

Table 6. Cont..

Sub-sub treatments (Presence or absence of 10t/ha of compost)					
SS1. With compost	**4354.9**	**1130**	**5484.9**	**9780**	**1.78a**
SS2. Without compost	**4354.9**	**1130**	**5484.9**	**7260**	**1.32b**
S.Ed.±					**0.085**
CD (p = 0.05)					**0.182**
Interaction (MxS)					
S.Ed.±					**0.06**
CD (p = 0.05)					**NS**
Interaction (MxSS)					
S.Ed.±					**0.05**
CD (p = 0.05)					**NS**
Interaction (SxSS)					
S.Ed.±					**0.06**
CD (p = 0.05)					**NS**
Interaction (MxSxSS)					
S.Ed.±					**0.09**
CD (p = 0.05)					**NS**

Means followed by the same letter are not significantly different at 5% probability level. M=main plot effect, S=subplot effect, SS=sub-sub plot effect, CD= critical difference, S.Ed.± = standard error of deviation

CONCLUSIONS

Based on the results, it was concluded that application of straw mulch and compost have increasing effect on red onion yield, leaf relative water content, gravimetric soil moisture content and water use efficiency. However, since highest red onion bulb yield, yield components, soil and plant moisture status were recorded in highest soil moisture regime (1.5 IW/CPE ratio) tested, further studies are needed to find out the optimum water regime to achieve maximum crop yield and water use efficiency in sandy non-calcic brown soil in the dry zone of Sri Lanka.

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