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Evaluating the Effects of Different Watering Intervals and Prepared Soilless Media Incorporated with a Best Weight of Super Absorbent Polymer (SAP) on Growth of Tomato

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Abstract *- Super Absorbent Polymers (SAPs) have been used as water retaining materials in agricultural fields. They can release stored water and nutrients slowly as required by the plants. The aim of the present study was to evaluate the effects of a constant weight of SAP(3g/lkg of growth media) named GAM-sorb from Vietnam, on growth of tomatoes in three differently prepared soilless media and watering at five intervals. . Fifteen treatments were arranged according completely Randomized Design with three replicates. Experiment design was a two factor factorial. Experiment involved, three different soilless media mixtures; coir dust: paddy husks mixed in the ratios of 1:1, 1:2, and 1:4. 500g of each mixture was added 500 g of cattle manure to potting media. Additionally Five watering intervals were applied; daily, 1 day, 2 days, 3 days and 4 days. Data was analyzed by using Minitab 14 version. The analysis of data indicated that the interaction effect of number of flowers per plant, Relative Water Content (RWC), plant height, amount of chlorophyll (SPAD values) and percentage of dry weight / fresh weight and yield had no significance. All the treatments yielded an average of 10-12 fruits per plant. However, results indicated that media with 1:1; coir dust: paddy husk watered daily and 1 day interval produced a high yield (150 g/plant). Blossom end rot symptoms resulted in ones experimented with 2, 3 and 4 days watering intervals and coir dust: paddy husk media (4:1). Coir dust: paddy husk (1:1) media watered daily and 1 day interval added with SAP was the best for growth of tomato.*

Key words*: Watering intervals, Soilless media, Super Absorbent Polymer, Tomato*

1 INTRODUCTION

Super Absorbent Polymers (SAPs) are compounds that absorb water and swell into many times than their original size and weight. They are lightly cross-linked networks of hydrophilic polymer chains. The network can swell in water and hold a large amount of water, while maintaining physical dimension structure (Buchholz and Graham, 1997, Mahdavinia et al 2004). It was known that commercially used water-absorbent polymeric materials employed are partial neutralization products of cross linked polyacrylic acids, partial hydrolysis products of starch acrylonitrile copolymers and starch acrylic acid graft

copolymers. Most authors agree that when super water absorbent polymers are incorporated in the soil, the following can be observed; control of soil erosion and water runoff (Wallace and Wallace, 1990), increasing infiltration capacity (Zhang and Miller, 1996), increasing soil aggregate size (Wallace et al, 1986), reducing soil bulk density (Al-Harbi et al, 1999), increasing water retention (Johnson, 1984; Bres et al, 1993), improving the survival of seedlings subjected to drought (Huttermann et al, 1999)), lengthening shelf-life of pot plants (Gehring et al, 1980), improving nutrient recovery from applied fertilizers (Smith et al, 1991; Bes et al, 1993), improving nutrient uptake by plants grown in poor soil, minimizing nutrient losses through leaching under highly leached conditions, (Mikkelsen, 1994) and reducing irrigation frequency (Taylor et al, 1986).

At present urban people all over the world are interested in practicing crop cultivation as a hobby and as a way to generate an income to support the economy of the family. One of the major problems faced by the urban agriculturists in Sri Lanka is difficulty in finding good quality soils. Daily watering has also become a concern due to their busy life and costly water bill. SAPs are becoming popular as commonly applied in soil cultivations to overcome the water scarcity. Hence, there is a possibility to apply SAPs to soilless culture too. According to Bres et al. (1993), SAPs could be used to find out the influence of gel additives on nitrate, ammonium and water retention ability and better growth of tomato in soilless medium.

The present study focused to evaluate the effects of growth of tomato on different moisture in growth media prepared by adding five watering intervals and three soilless media incorporated with the best weight of Super Absorbent Polymer(SAP) named GAM-sorb, (imported from Vietnam) under plant house.

2 LITRETURE REVIEW

2.1 Super Absorbent Polymers

Super Absorbent Polymers (SAPs) were first introduced into the agriculture and diaper industries about four decades ago (Omidianet al., 2005). Since then, where an excellent water-holding property was of primary concern, SAPs extended their applications to other industries.

SAPs are structurally cross-linked, highly swollen and hydrophilic polymer networks capable of absorbing a large amount of water or aqueous saline solutions, practically 10 to 1000 times of their original weight or volume (Ramazani-Harandiet al., 2006), in relatively short periods. SAPs are not dissolved in the media they are in due to their three-dimensional structure. Kabiri *et al*. (2003) and Ramazani-Harandiet al. 2006 described that the desired features of SAPs include high swelling capacity, high swelling rate and good strength of the swollen gel. The water absorbency of a SAP is greatly influenced by its composition, molecular weight, degree of cross linking, the molecular conformation of the polymer, and by the properties of liquids to be absorbed (Chen and Tan, 2006).

SAPs are commonly based on acrylic monomers such as acrylamide, acrylic acid and salts of the acid (Omidianet al., 1998). Commercially, SAPs are majorly produced with acrylic acid as a key component (Lanthong et al., 2006). The super-swelling characteristics of SAPs equipped them for use in water absorbing applications such as disposable diapers, feminine napkins, agriculture and cosmetic.

Recently, the diverse applications of superabsorbent polymers are still being expanded to many fields including agriculture and sealing composites, horticulture, drilling fluid additives, artificial snow, medicine, and so on (Li and Wang, 2005).

2.1 Applications of the Super Absorbent Polymer in Agricultural Field

In arid and semi-arid regions of the world, intensive research on water management is being carried out and use of Super Absorbent Polymers (SAP) may effectively increase water use efficiency in crops. The application of SAP for stabilizing soil structure resulted increasing infiltration and reducing water use and soil erosion in a furrow irrigated field (Lentz and Sojka, 1994, Lentz et al., 1998, Trout et al., 1995). The SAP can be used effectively in areas of rain fed agriculture and sprinkler irrigation (Ben - Hur et al., 1989; Levy et al., 1992; Shainbery and Levy 1994). Super absorbents use as soil additives to increase the water retention of soils, which can replace peat, the traditional moisture retention aid for soil (Barbucci et al., 2000). Generally, SAPs are applied to the soil at a concentration between 0.1 to 0.5% by weight (Buchholz and Graham 1998). Below this range, the effect of soil additive is negligible and above this range the soil can become too spongy when it is fully saturated. Miller et al., 1979; suggested that the performance of SAP as water-retaining additive is greater in soils that are well draining such as sand. When polymers are incorporated with soil, it is presumed that they retain large quantities of water and nutrients. These stored water and nutrients release as required by the plants. Thus, plant growth could be improved with limited water supply. Johnson et al.1984; reported 171 to 402% increase in the water retention capacity when polymers were incorporated in coarse sand. Addition of a polymer to peat decreased water stress and increased the time to wilt (Gehring and Lewis, 1980). Results from the literature also showed that increased water retention capacity attributed to polymer addition in to the soil significantly reduced irrigation frequency (Gehring and Lewis 1980; Flannery and Busscher, 1982) and total amount of irrigation water required (Taylor and Halfacre, 1986).

The use of hydrophilic polymers in soils to improve both the nutritional and water status of plants has attracted considerable interest recently. When used correctly, SAP have the potentials to improved soil physical properties, reducing soil erosion and nutrient loss, and improving runoff water quality (Shainberg et al., 1990, Shainberg et al., 1994), increasing seedling survival (Gray 1981), increasing crop growth and yield (Yazdani et al., 2007) and reducing the irrigation requirement for plants (Flannery and Busscher, 1982).

Blodgettv et al., (1993) found that adding SAP to the soil matrix increased the water holding capacity as well as water available to plants. The SAP also prolonged water availability for plant use when irrigation stopped (Huttermann et al., 1999). Use of SAP

prolonged the time of the soil evaporation (El-Amir et al., 1993). The SAP usually has some effect on plant establishment with the greatest benefit for moisture loving plants planted under dryer condition. The use of hydrophilic polymer materials as carrier and regulator of nutrient release has shown promise for reducing undesired fertilizer losses, while sustaining vigorous plant growth (Mikkelsen, 1994).

2.4 Super Absorbent Polymer -GAM-Sorb

Vinagamma affiliated to Vietnam Atomic Energy Commission has recently successfully manufactured water super-absorbent namely GAM-Sorbs which, when combined with organic or micro organic fertilizers, may raise plant productivity from 10-30% more than usual. GAM-Sorb is made up from environmentally friendly and naturally born polymers, which may regenerate or degenerate in the soil. In order to make GAM-Sorb, manufacturers have to apply radiation techniques as physical agent to denature naturally born polymers (starch, for example), derivatives from cellulose, or poly-glutamic acid. The product may degenerate into humus, carbon dioxide, and water. GAM-Sorb, when combined with organic or micro organic fertilizers, may raise plant productivity from 10-30% more than usual, that is to say, without GAM-Sorb (http://www.vinagamma.com).

3 METHODOLOGY

3.1 Location and variety selection

The study was carried out in the plant house at the Open University of Sri Lanka during the period January to May 2014.Tomato variety "Bathiya" was selected for the experiment since it shows less vulnerability to diseases compared to other tomato varieties.

3.2 Preparing soil less media

Three soilless media were prepared. Each medium was prepared with mixing coir dust and paddy husk in the ratios of 1:1, 2:1, and 4:1. 500 g from each mixture and 500 g of sterilized powdered cattle manure were added to a pot and kept in a shady place for decomposing for four months.

Three different soilless media,

A - Coir dust: Paddy husk (1:1) + 500 of cattle manure

B - Coir dust: Paddy husk (2:1) + 500 of cattle manure

C - Coir dust: Paddy husk (4:1) + 500 of cattle manure

3.2.1 Analyzing samples

Initially powdered cattle manure was analyzed in the laboratory of Agriculture and Plantation Engineering, Faculty of Engineering Technology, the Open University, Nawala Nugegoda. pH was measured using pH meter. Electrical conductivity meter used to determine Electrical Conductivity (EC), phosphorus, potassium and nitrogen concentrations were evaluated using Palin test photometer.

3.3 Method and experimental design

Best selected SAP rate (3g per 1 kg of growth media from Fernando et al., 2012) was added to each pot. Five (05) watering intervals were applied; 1 day, 2 days, 3 days and 4 days and for the control water applied daily. Fifteen (15) treatments were used with three soilless media and five (05) watering intervals. Treatments were arranged in a completely randomized design with three replicates.

T1 - (3g SAP + A + Daily watering (C))

T2 - (3g SAP + A + 1 day)

T3 - (3g SAP + A + 2 days)

T4 - (3g SAP + A + 3 days)

T5 - (3g SAP + A + 4 days)

T6 - (3g SAP + B + C)

T7 - (3g SAP + B +1day)

T8 - (3g SAP + B +2 days)

T9 - (3g SAP + B +3 days)

T10 - (3g SAP + B +4 days)

T11 - (3g SAP + C +C)

T12 - (3g SAP + C +1day)

T13 - (3g SAP + C +2 days)

T14 - (3g SAP + C +3 days)

T15 - (3g SAP + C +4 days)

Two weeks after sowing one seedling was transplanted in each pot. After transplanting, plants were watered daily for seven (07) days to field capacity measured by pressure plate until plants were well established. Additional fifteen pots were placed inside the plant house without adding SAP and plants to determine the weight losses in growth media due to evaporation. They were watered following the watering intervals with three replicates. Before the watering the pots were weighted and confirmed the constant weight in all pots. According to the weight losses amounts of water required for each pot was calculated as follow,

Weight of dried soil + pot = W_1

Weight of dried soil + pot + added water to fulfilled the Field Capacity = W_2

Weight losses from evaporation =W_2-W_1

W2-W1 amount of water was added to each pot during watering. Every two weeks, equal volume of foliar fertilizer was applied to each plant. Following organic mixtures were

used as fertilizer solutions to inhibit degradation of SAP with Inorganic fertilizer and nutrients deficiency. Diluted fermented cattle manure solution (1L per 7L tap water), diluted wormy wash solution, prepared by recommendation of department of Agriculture (1L per 5L tap water) and diluted fermented leaves mixture (fresh Gliricidia (Gliricidiasepium), IpilIpli (Leucaenaleucocephala) and Undu Piyaliya (Desmodiumtriflorum) in the ratio of 1:1:1) (1L per 7L tap water). Major nutrient element composition; nitrogen, phosphorus and potassium were estimated in all three diluted organic solutions using Palin test photometer. In addition, pH, Electric Conductivity of each solution was measured. During the period of seedling, flowering and fruiting, fermented leaves, cattle manure and wormy wash solutions were mixed respectively to the water used twice over the given period. Pests were controlled only when the infestation was seen to be a threat to normal plant growth. Hand weeding was done when necessary. Number of flowers per plant was recorded at seven (07) day intervals, Weight of the harvested fruits per plant was recorded at three (03) day intervals in grams (g), Leaf area was measured randomly selected mature five (05) leaves per plant using leaf area index, Chlorophyll content in plant leaves (SPAD values) were measured in randomly selected fully expanded five (05) leaves per plant using the SPAD meter, Relative water content (RWC) was measured on flag leaves. Immediately after cutting the base of lamina, leaves were sealed in plastic bags and quickly transferred to the laboratory. Fresh weights (FW) were determined within 1h after excision. Turgid weights (TW) were obtained after soaking leaves with distilled water in test tubes for 16 to 18 hours at room temperature under low light condition. After soaking, leaves were carefully blotted dry with bloating paper to determine turgid weight. Dry weights (DW) were obtained after oven drying for 72h at 70 0C. The RWC was calculated according to Schonfeld et al. (1988) as RWC= [(FW-DW)/ (TW-DW)]. A fruit defect (cracks, blossom end rot) per plant was recorded at two (02) day intervals. Ratio of dry weight/fresh weight of each plant was measured in grams (g). In addition, relative humidity and temperature was measured daily using wet and dry bulb thermometer inside the plant house in order to study the general climatic changes in the area. The pots were placed inside the plant house according to the Completely Randomized Design (CRD) with the recommended spacing of tomato 45 × 45 cm. Statistical analysis was carried out through Minitab 14 software version.

4 RESULTS

Tested cattle manure samples had the appropriate amount of nitrogen (295mol/l), phosphorus (95 mol/l), potassium (430 mol/l) and organic matter. Electric Conductivity (EC) and pH value were, 1.32 dS/m and 7.33 respectively. The average temperature and relative humidity of the research area was 35 0C and about 65%. The nutrient compositions of organic solutions used as liquid fertilizer were given in table 1. Average pH values of solutions were between 6.77 and 7.4 and EC was varied between 0.1 mS/m and 5.1 mS/m. According to the measured pH values and EC, all solutions were low in acidity and alkalinity. Moreover, all organic solutions were with high amount of nitrogen, and the highest was observed in wormy wash compared to other two organic

solutions. Fermented leaf solution had the highest phosphorous level. Highest amount of potassium concentration was observed in cattle manure solution compared to other two solutions.

According to the results indicated in table 2, except number of flower per plant all other measured parameters; plant height, RWC of plant leaves, SPAD values, leaf area and percentage of (DW/FW) were not significant (P>0.05) for growth media. According to the watering intervals, there was a significant difference between number of flowers per plant, plant height and leaf area (P<0.05) other than RWC, SPAD values and percentage of (DW/FW). Further, the interaction effects of all measured parameters were not significant. According to results in table 3, number of flowers per plant, plant height, SPAD values of plant leaves and leaf area were highest at growth media having (1:1) coir dust: paddy husk. RWC and percentage of (DW/FW) of whole plant were highest in growth media having the ratio of (4:1) coir dust; paddy husk. According to watering intervals except RWC and SPAD values of plant leaves other measured parameters were highest in daily watering compared to other watering intervals. The variations of mean values for treatment combinations were shown in figure 1 to 6. (Mean values obtained from analysis data were manually categorized as a>ab>b>bc>c>cd>d for clear identification). According to these figures, except RWC and SPAD values other measured parameters were highest in treatment 1 which had (1:1) coir dust: paddy husk and daily watering added plant compared to other treatment combinations. Number of flowers per plant, SPAD values and leaf area were lowest in treatment added with (4:1) coir dust: paddy husk and after four day water added plant other than RWC, plant height and percentage of (DW/FW). Plants of all the experiments were yielded with 10-12 fruits per plant. Out of them, (1:1) coir dust: paddy husk applied and daily and 1 day after watering plants were high yielded (150 g/plant). Plants with 2 day, 3 day, 4 day watering intervals and (4:1) coir dust: paddy husk growth media, blossom end rot disease were observed.

Table 1 Characteristics of organic solutions

	De-ionized water	Wormy wash	Leaf solution	Cattle manure
pH	7.0	6.77	7.4	7.1
Electrical conductivity(mS)	0.1	4.1	5.1	1.7
Nitrogen (mg/l)	-	360	300	320
Phosphorous (mg/l)	-	22	152	37
Potassium (mg/l)	-	360	60	450
Relative density	1.0	1.0	1.0	1.1

Table 2 Variations of probability values on growth media, watering interval and its interaction on growth parameters

Term	No of Flowers	Plant height (cm)	RWC	SPAD Value	Leaf area cm^2	DW/FW (%)
Growth- meadia	0.006	0.494	0.397	0.063	0.215	0.569
Watering- intervals	0.000	0.000	0.295	0.610	0.009	0.289
Interaction	0.077	0.495	0.869	0.488	0.783	0.227

Table 3 Variation of minimum and maximum mean values of measured parameters according to the growth media and watering interval

Term	No of Flowers	Plant height (cm)	RWC	SPAD Value	Leaf area cm^2	DW/FW (%)
Growth media						
A	24	117.47	71.52	63.22	22.00	25.46
C	19	113.07	73.31	60.31	20.35	27.98
Watering- intervals						
Control	27	134.20	71.17	61.34	23.48	29.47
4 days	16	96.33	73.48	62.19	18.87	23.97

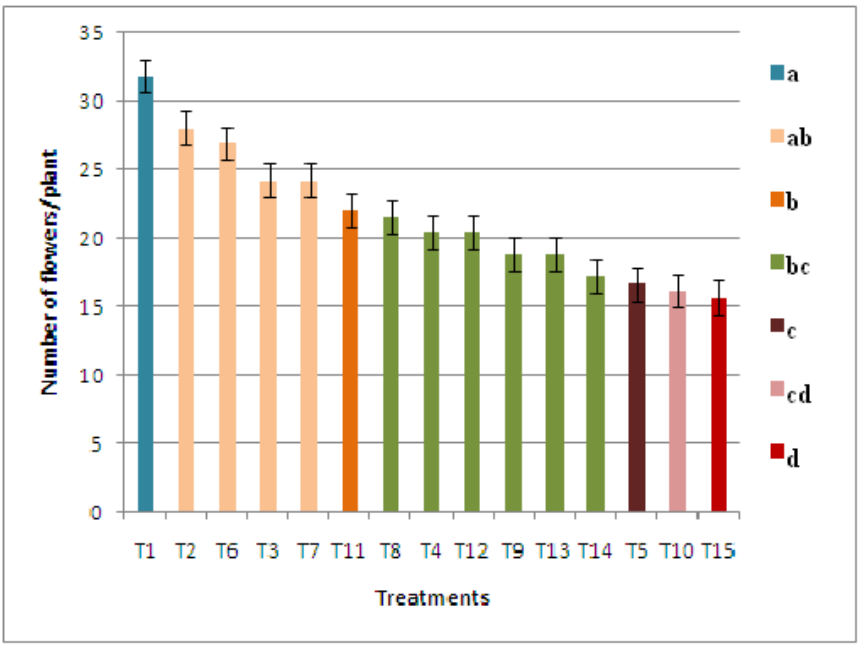

Figure1 Variation of means of treatment combinations for number of flowers per plant

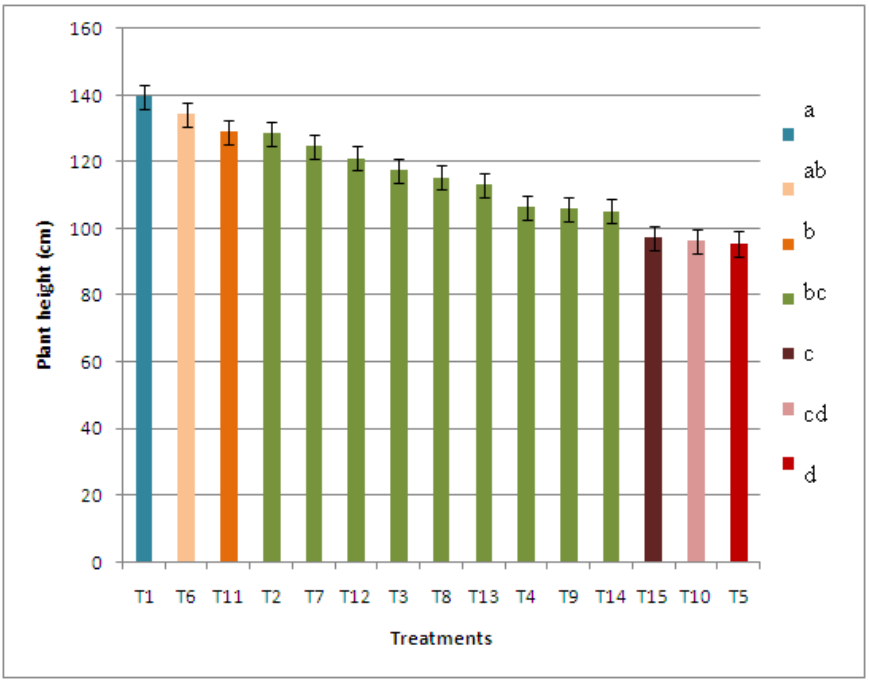

Figure2Variation of means of treatment combinations for plant height

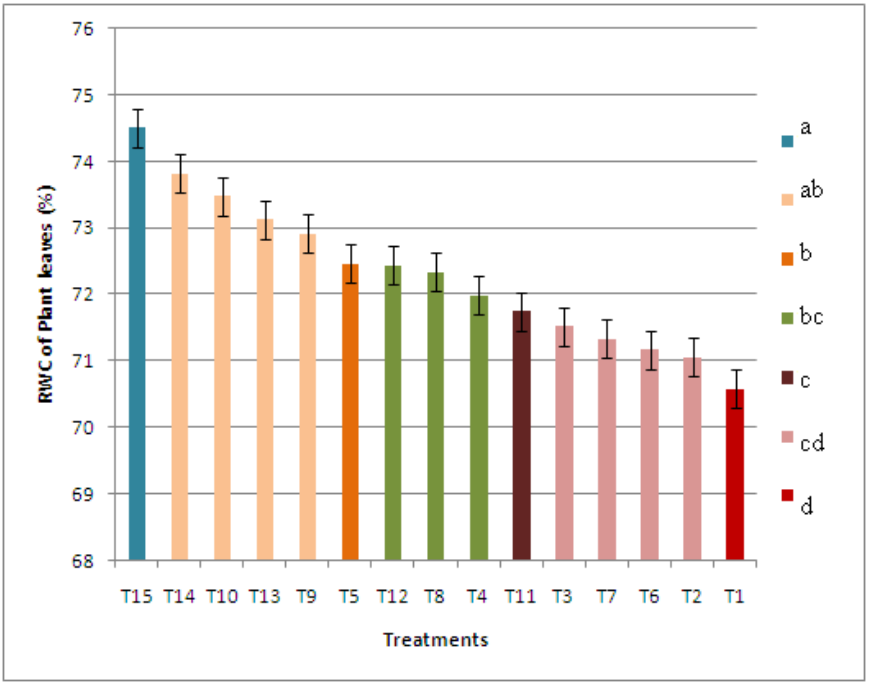

Figure 3 Variation of means of treatment combinations for RWC of plant leaves

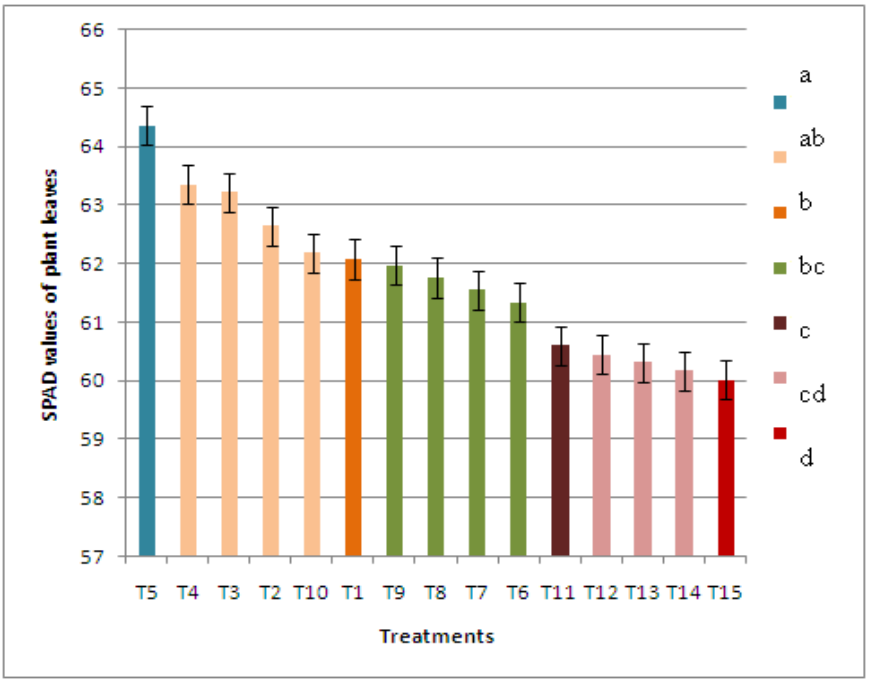

Figure 4 Variation of means of treatment combinations for number of flowers per plant

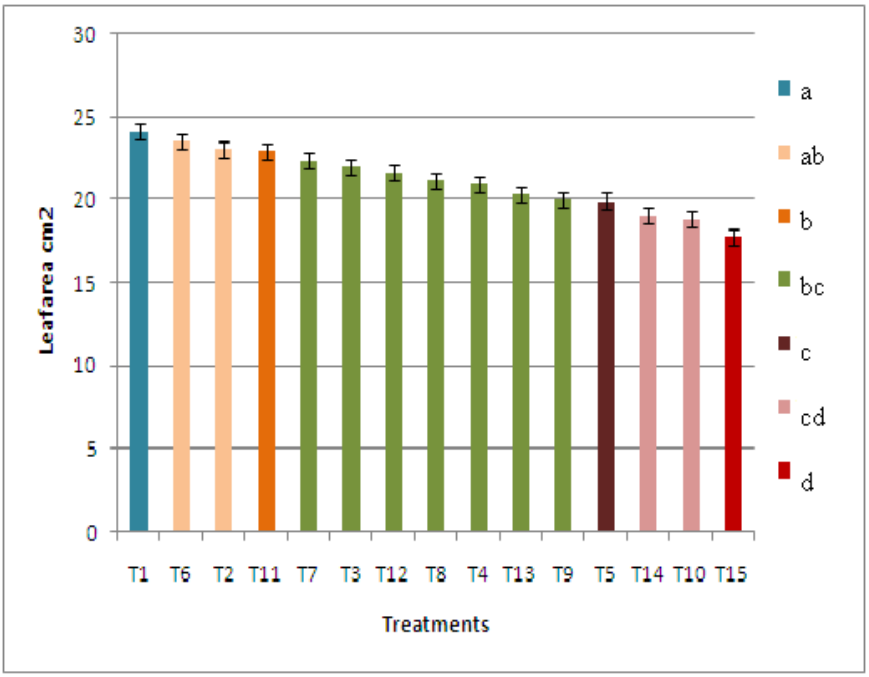

Figure 5 Variation of means of treatment combinations for Leaf area

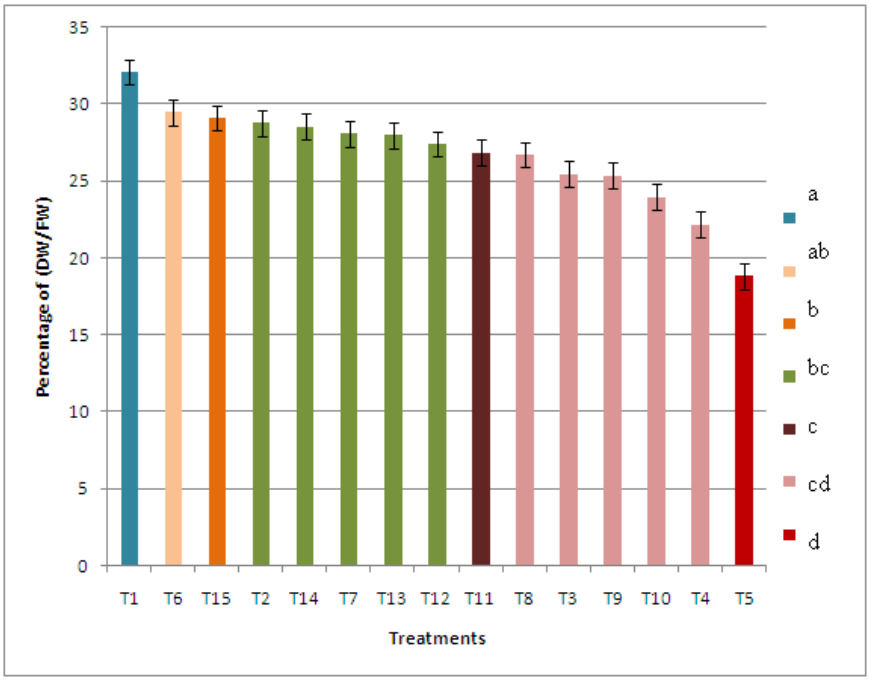

Figure 6Variation of means of treatment combinations for percentage of (DW/FW)

Plate1Symptom appeared in fruits affected with blossom end rod

5 DISCUSSION

SAPs have been used in agricultural and horticultural fields (Johnson, 1984; Mikkelsen, 1994; Yazdani et al., 2007) due to their ability to retain water and nutrients when incorporated into the soil. The stored water and nutrients are released slowly in required amounts to the plant rihzosphere, making them available to the plants under limited water supply conditions (Huttermann et al., 1999). Yazdani et al., 2007, have reported that the yield, harvesting index, canopy height, total dry weight, number of flowers per plant, leaf area and crop growth rate increased when irrigation interval was 6 days compared to 8 and 10 days . The Ghasemi et al., 2008; reported that using hydrophilic gels had positive and significant effect on number of flowers per plant, leaf area, plant height, root/shoot proportion and coverage area in drought stress in 5 day watering intervals using 0.8% of hydrogel. However, results of the present study indicated that not

only best weight of SAP but also condition of soilless media and watering intervals were affects that caused highest yield with highest number of flowers per plant, plant height, leaf area, percentage of (DW/FW) on (1:1) coir dust: paddy husk added to growth media and daily and 1 day watered treatments compared to other treatments. Morphological parameters observed during fruiting stage did not show significant difference in all three growth media (all plants showing nearest value). According to the results of Vidana Arachchi et al., 1997 incorporated rates of coir dust to the sandy soil increased moisture retaining ability. However lowest rate of coir dust consisting of (1:1) coir dust: paddy husk media has more porosity compared to other soilless media. When applying water daily and at one day interval, water infiltration and nutrient wash-off ability may increase. Due to this highest yield and growth parameters obtained with (1:1) coir dust: paddy husk and daily and 1 day watered media.

Additional, plants showed blossom end rot diseases symptoms in less porosity media having the ratio of (4:1) coir dust: paddy husk media and in media applied with higher watering intervals; 2 day, 3 day and 4 day. The reason could be the nutrient imbalance and physiological stress incurred due to water scarcity. Another reason for blossom end rot is lack of calcium in the fruits, by reducing cell membrane permeability leading to swelling of the cells followed by leakage and destruction of the membrane structure (Blossom-End Rot of Tomato, Pepper, and Eggplant, HYG-3117-96, 2013). There is also a reduction in growth of new cells. This causes the characteristic dark, sunken areas. A similar problem can arise when fertilizer is added to dry soil closer by around the plants, because the concentrated nutrients in the soil water will restrict water uptake by the plant. Additionally, some fertilizer ingredients - ammonium salts for example - compete with calcium to access the plant roots, further exacerbating the calcium deficiency (Vidana Arachchi et.al, 1997).

6 CONCLUSIONS

Condition of soilless media and watering intervals may affect growth of tomato with SAP. Growth environment of (1:1) coir dust: paddy husk and daily and 1 day watered treatment may result in good tomato yield without infestation of blossom end rod and other toxic diseases.

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Effect of Mulch on Soil Properties, Growth and Yield of Chili (*Capsicum annuum L.*) Exposed to Temperature Stress due to Global Warming

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Abstract - *Understanding the effect of temperature and water stress on growth and yield of crops, and also identifying suitable management options to sustain the productivity under unexpected changes in the natural environment due to global warming are of timely important. When temperature exceeds the optimum for biological processes, crops often respond negatively with a steep drop in net growth and yield. Higher air temperature also affects the soil temperature and soil fertility which degrades soil to sustain successful plant growth. Therefore, the objective of this study is to assess the effect of mulch on soil properties, growth and yield of Chili plants exposed to temperature stress due to global warming. Chili was selected as it is widely cultivated in most of the farmer's field in the dry zone of Sri Lanka and one of the profit making cash crops. Experiment was conducted in the temperature regulated poly tunnels with ambient temperature, 32°C, and 34°C. Coir dust, straw and saw dust were used as mulch types. Plants were watered to the field capacity level avoiding any sort of water stress conditions. According to the results, soil organic matter content, moisture content, potassium and phosphorus contents were highest in sawdust mulched soil even at 34°C. Further the sawdust mulched soil maintained a neutral pH which would have facilitated the good cation exchange capacity and, nutrient availability for plants. In addition the sawdust mulched soil maintained a lowest soil temperature of 28.6°C even at stressful temperature of 34°C, which would have facilitated the physiological activities of the chili plant favorably and therefore the yield of the chili plants in sawdust mulch maintained the highest significant yield of 315g/plant (within the recommended yield range of the Department of Agriculture) among the other treatment even at stressful temperature. Results showed that the high temperature effect on soil has minimized by the use of sawdust mulch followed by coir dust mulch. Therefore these findings could be used by farmers to cope with extreme weather situation prevails in the dry zone of Sri Lanka.*

***Key words**: Mulch, Temperature stress,, Chili, global warming*

1 INTRODUCTION

In Sri Lanka, the agriculture sector is the backbone of the economy. Specially, the agricultural sector in Sri Lanka is highly depending on climate to cope with the

irregularity in extreme events of the weather patterns. Therefore, any changes in climate variability may bring about drastic effect to the farming systems of the country. Sri Lanka's dry zone agricultural output will decline significantly in the next 20 to 30 years because of reduced rainfall and increased temperature(De Silva, 2006).

Global warming, driven by the rising of greenhouse gases especially CO_2 in the Earth's atmosphere, could cause many changes to ecosystems of the world. One of the most important changes is the climate and is a long-term shift or alteration in the climate. Temperature and precipitation are the most important climatic parameters for crop growth. Therefore, scientists have used available climatic data and information into several large-scale models of the atmosphere. These models are used to predict changes in temperature, precipitation, radiation, and other climate variables caused by increased greenhouse gases in the atmosphere.

Although, there are differences between these projections, the report of the Intergovernmental Panel on Climate Change (IPCC) estimated that the mean global temperature might be increased from1.4°C to 5.8°C (2.52°F –10.44°F) during 21st century. In the past 100 years, the global average surface temperature has increased by 0.6°C (1.08°F) (IPCC 2001). Temperature increase during 1961 to 1990 has reported in Colombo as 0.0164°C per year and in Anuradapura0.0364°C per year (Fernando and Chandrapala, 1995). The average annual temperature for 2050 modeled using General Circulation Model (HadCM3) is predicted to increase by 1.6°C (A2 scenario) and 1.2°C (B2 scenario). The highest mean temperature was predicted in Anuradhapura by 2.1°C (A2), 1.6°C (B2). During the southwest monsoon period (May to September) the overall increase in mean annual air temperature across the island is predicted to increase by 1.6°C (A1) and 1.2°C (B2) (De Silva, 2006). Further the Northeast monsoon rainfall is also predicted to decrease. Therefore the decreased rainfall and increased in temperature will increase the evapo-transpiration and soil moisture deficits. Agricultural activities in the dry zone may be affected by predicted climate change in Sri Lanka (De Silva *et. al.,* 2007).

1.1 Impact of temperature stress on crops

Important effect of high temperature is accelerated physiological development, resulting in hastened maturation and reduced yield. When temperature raises too high heat destruction of protoplast result in cell death. Some reports show that an increase in temperature by a single degree above normal can lead to a significant reduction in growth and yield (Pastori and Foyer, 2002). Higher air temperatures will also be felt in the soil, where warmer conditions are likely to speed the natural decomposition of organic matter and to increase the rates of other soil processes that affect fertility.

1.2 Impact of mulch on soil

Mulching improve the soil agro-physical properties (Strizaker et al., 1989). Mulching also minimizes the use of N fertilizer (Jones et al., 1977), warms the soil (Singh et al., 1988), improves the soil physical condition, and suppresses weed growth (Iruthayaraj et al., 1989) and could account for increased yield (Ravinder et al., 1997).

Agricultural management practices, such as mulching and irrigation can change the characteristics of the soil surface and hence influence the hydrothermal properties of the soil (Zhang et al., 2009). For example, mulching can affect the temperature and moisture content of the soil and directly influence the grain yield of crops. Straw mulching (SM) system can conserve soil water and reduce temperature because they reduce soil disturbance and increase residue accumulation at the soil surface (Zhang et al., 2009).

This study intends to identify the suitable mulch to mitigate the consequences of higher temperature stress due to unexpected weather events by evaluating the effect on soil properties, growth and yield parameters of Chili (*Capsicum annuum* L.) variety MI2. Chiliis one of the most widely cultivated crops throughout the year in both y*ala*(dry)and *maha*(wet)seasons. In this study plants will be applied with adequate water without any water stress according to the previous study results on chili (Gunawardhana et al, 2011).

2 MATERIALS AND METHODS

2.1 Growing conditions

This study was conducted during October 2010 to July of 2013(6 seasons) in temperature regulated poly tunnels constructed in the agricultural field of the Open University of Sri Lanka, Nawala, Nugegoda. Two poly tunnels was maintained at 32°C maximum temperature and34°C and the third experiment set was outside the polytunnel as the ambient temperature. The cultivar MI2 of Chili was used in this study. Chili was raised in nursery and transplanting was conducted 4 weeks after planting (4WAP) Chili plants from the nursery were planted into individual plastic pots (1 plant/ pot in 40 cm diameter and 45 cm deep pots)filled with compost and reddish brown earth soil from Anuradhapura.

All extraction runs and analyses were carried out at least in duplicate and in randomized order. The mean values being reported with five replicates to reduce the random error. Plants were grown at 3 different conditions as indicated in the Table 1. Three types of mulches (Coir dust, straw and saw dust) were used as an average depth of 2.2 inches of layer on the soil surface along with a no mulch condition. Plants were maintained without water stress by applying water to keep the soil moisture at field capacity level throughout the growing season. Different environmental conditions are shown in Table 1.Management of the crop; cultural practices and fertilizing were done according to the recommendations of the Department of Agriculture 2010. The experimental design was Completely Randomized Design (CRD) with factorial treatment structure. Temperature and mulches were taken as factors. Soil and growth parameters of Chili were investigated during the growing and reproductive periods.

Table 1Three different environment conditions of the experiment

No	*Environmental conditions*
Condition 1 – Poly Tunnel	34⁰C Poly tunnel • Three types of mulches on soil – coir dust (M1) /straw (M2)/sawdust (M3)/No mulch(M0)
Condition 2 – Poly Tunnel	32⁰C Poly tunnel • Three types of mulches on soil – coir dust (M1) /straw (M2)/sawdust (M3)/No mulch(M0)
Condition 3 – Open Space	Ambient temperature • Three types of mulches on the soil – coir dust (M1) /straw (M2)/sawdust (M3)/No mulch(M0)

2.2 Temperature control in the poly-tunnels

The variation of temperature inside the poly tunnel and the ambient temperature outside over a period of 24 hours was observed as shown below (Figure 1). Though the each sensors and exhaust fans were used to maintain the set temperature inside the polytunnel, the temperature during night time falls below the maximum temperature set for that particular poly tunnel. However the temperature maintained inside the poly tunnels were always higher than the ambient temperature; therefore temperature stress was forced on the plants throughout the day.

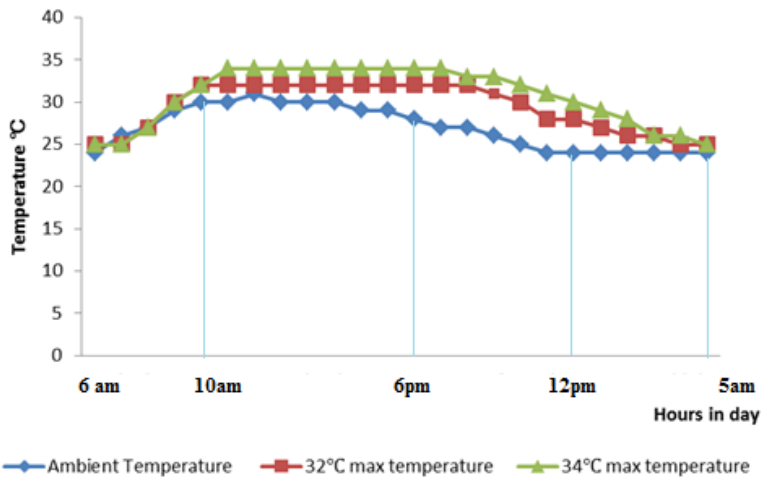

Figure 1 Temperature variation inside and outside the poly tunnel(starting from 8am (1))

2.3 Data Collection

Estimating the physical characteristics of the plants, transplant success (survival rate) was estimated by the percentage of plants that showed successful establishment at 3 weeks after planting (WAP). Due to temperature stress, there are changes in vegetative growth stages of the crops before getting in to fruit pods. Therefore the physical characteristic of plants such as height of the plant and number of leaves were measured weekly. Other than these germination rate, date to bloom first flower, length of flowering stage, number of flowers and number of pods per plant and yield per plant were also estimated. Soil related chemical parameters were estimated such as pH by direct method (electronic pH meter). EC (measured using the Conductivity meter), organic matter determined using the ASTMD2974-Standared test method, Moisture percentage and bulk density were estimated using the Gravimetric method. Soil P and K Content were measured using the spectrophotometer meter and the soil temperature was measured using the temperature probe in soil analysis kit.

3 RESULTS AND DISCUSSION

3.1 Effect of Mulch on Soil Properties

3.1.1 Soil pH

Average soil pH among the treatments ranged from 5.5 -7.8 (Figure 2). Generally, plants mulched with saw dust and straw maintained natural (values around6- 7) pH values than the others ($p<0.05$). Soil pH is lower in plants mulched with coir dust (less than 6) than no mulch. In sawdust mulch the neutral pH was maintained at 6-6.5 even within the stressful conditions, neutral pH encourage the decomposition rate and it is also the preferred soil pH range for good growth and optimum yield of chili.

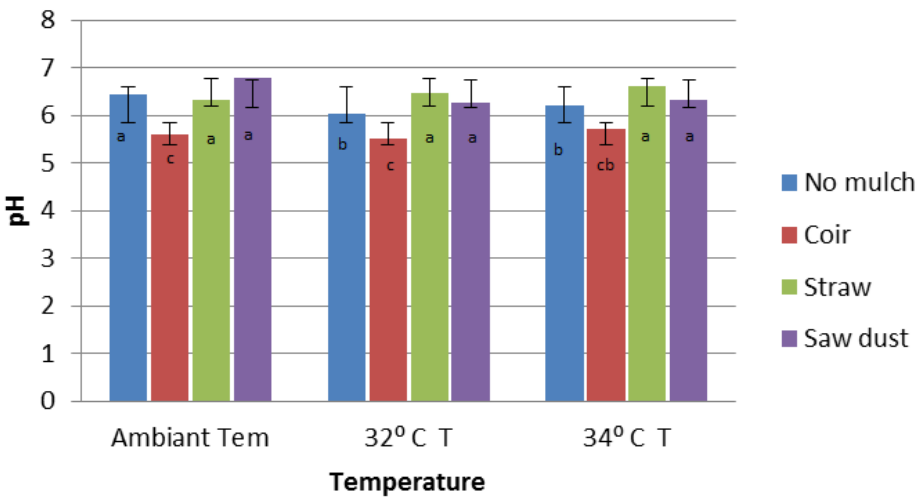

Figure 2 Effect of coir dust, straw and saw dust as mulch on soil pH

3.1.2 Soil electrical conductivity (EC)

Average soil EC among the treatments ranged from 0.075 -0.09ds/m (Figure 3). According to the results there is a significant difference with temperature ($p<0.05$). Significant variation has shown between mulches. The highest EC was reported from coir dust treatment in ambient temperature followed by Straw and then Saw dust mulch. In stressful temperature (34°C) treatments and lowest EC was shown from no mulch condition and the highest was obtained in Sawdust mulch. Agricultural management practices can change the characteristics of the soil surface and influence the hydrothermal properties of the soil. For example, mulching can affect the temperature and moisture content of the soil (Li *et al.*, 1999). EC is proportionally increased with the moisture content.

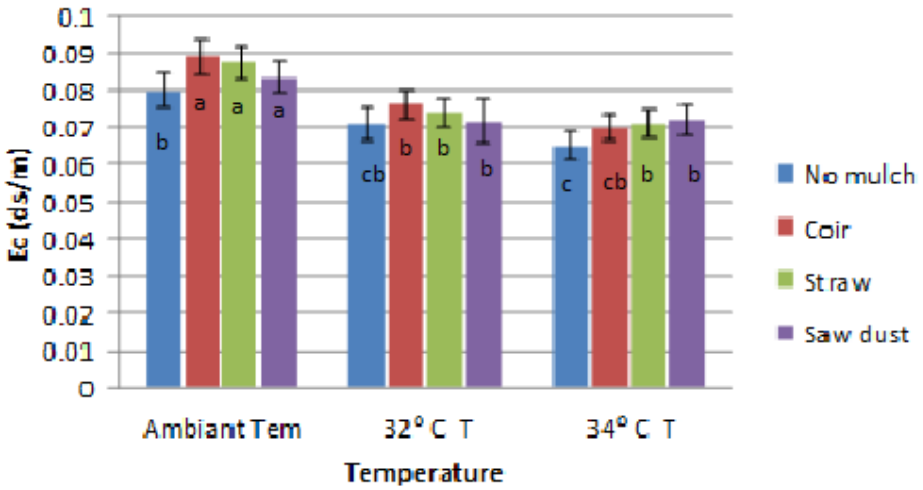

Figure 3 Effect of coir dust, straw and saw dust as mulch on soil electrical conductivity

3.1.3 Organic matter content

Average soil organic matter content among the treatments ranged from 2.5 -3.7% (Figure 4). According to the results there is no significant difference with temperature. Significant variation has shown between mulches($p<0.05$). The highest organic matter content was found from saw dust in 34°C and in ambient temperature treatments. Saw dust mulch has the best suitable environment for biodegradation and root penetration due to the neutral pH balance, even in stressful temperature. The lowest organic matter content was shown in no mulch condition in all temperature conditions.

Organic matter is a key component of soils affecting their physical, chemical and biological properties and is important as a source of energy and nutrient elements for soil ecosystem. Maintenance of sufficient levels of organic matter in soils is prerequisite for sustainable and high production of crops according to Arafat (1994).The cation exchange capacity of a soil is greatly influenced by the organic matter level. A high organic matter soil will have a much higher cation exchange capacity than a low organic matter soil.

Some of the properties influenced by organic matter include soil structure, soil compressibility and shear strength. In addition, it also affects the water holding capacity, nutrient contributions and biological activity, water and air infiltration rates. Research finding indicates the vital role of bio-organic fertilization in more release of available nutrient elements to be absorbed by plant roots and this in turn increase dry matter content in the different peanut and lentil plant organs (Saber and Kabesh, 1990). Mulching has increased soil moisture, organic matter contents leading to suitable environment for root penetration. The soil organic matter increased due decomposition of applied mulch. Organic matter is a key component of soils affecting their physical, chemical and biological properties and is important as a source of energy and nutrient elements for soil ecosystem Applications of crop residue mulches increase soil organic carbon content in soil (Havlin *et al.*, 1990) concluded that organic matter was significantly higher when more mulch was applied to soil.

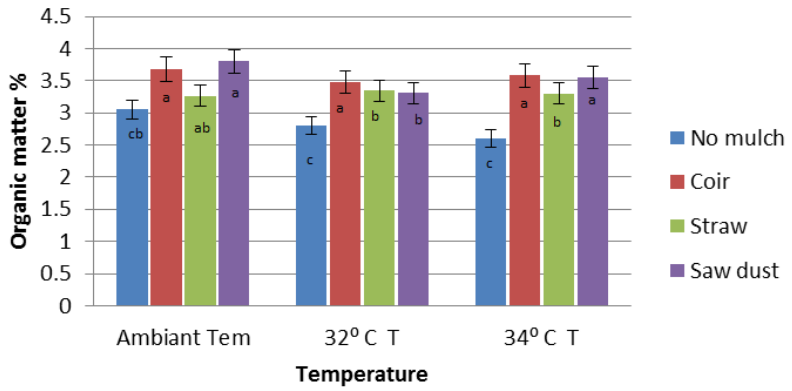

Figure 4 Effect of coir dust, straw and saw dust as mulch on soil organic matter

3.1.4 Moisture content

Average soil moisture among the treatments ranged from 17.4%-19%. According to the results there is no significant difference with temperature ($p<0.05$). Significant variation has shown between coir dust and sawdust with no mulch condition. The highest moisture percentage was reported from saw dust mulched treatments in ambient temperature. In stressful temperature (34°C) the coir dust was highest and followed by saw dust mulch. Manure and mulch can be used in soil and water conservation, since their appropriate use in soil treatment will reduce soil erosion. Fertile soil also produces higher yielding crops through this mulching treatment (Robert 1987).Organic mulches also reduce the evaporation of water depending on its characteristics (particularly fragment size and thickness) (Diaz *et al.*, 2005).

According to the HadCM3 model output for Sri Lanka, the North-East monsoon rains are predicted to decrease by 34% (A2) in selected locations in the country. Similarly, the annual average temperature is predicted to increase. These changes in rainfall and temperature, together with other climatic factors, will increase the potential soil moisture

deficit significantly (de Silva, 2009). Therefore mulching with saw dust or coir dust will help to maintain the higher moisture content even in stressful temperature. One of the most important characteristics of saw dust is the high water retention capacity.

Coir dust can store up to 8 times its dry weight on water. By applying a 15 cm thick coir dust mulch layer around coconut seedlings in Sri Lanka, irrigation could be reduced by 40-55% during dry season. In a pineapple coconut intercrop during dry season the top soil layer had a moisture content of 49% under coir dust mulch compared to 10% under a sandy ridge of the same height. Therefore Coir dust and saw dust mulches are well suited in high soil moisture deficit condition due to high temperature and low rainfall condition.

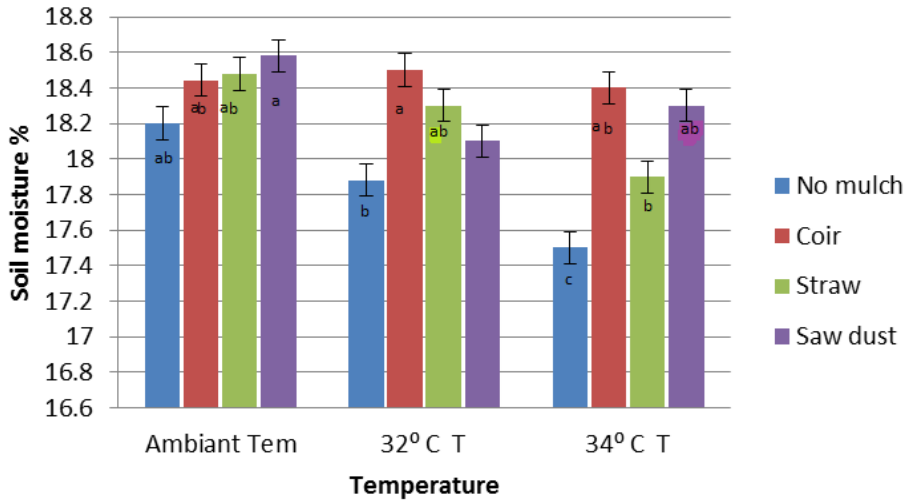

Figure 5 Effect of coir dust, straw and saw dust as mulch on soil Moisture content

3.1.5 Soil temperature

Average soil temperature among the treatments ranged from 17.8-33.9 °C. Soil temperature at the 5 cm depth was different due to the presence of mulch (Table 2). Soil temperature varied significantly with no mulch and mulched conditions ($p<0.05$).

Soil temperature was low in the morning and gradually increased until peaking at 2pm in all the treatments and then declined. Temperature under mulches was lower than that of the control plots for 32°C and 34°C in all the times. The saw dust mulch produced lowest (Table 2) soil temperatures even at stressful temperature at 34°C especially at 2pm when the photosynthetic rates are high. By providing lowest temperature for soil when the air temperature is 34°C helps the higher photosynthesis by the cooling effect to roots at 28.6°C. Heat loss from the soil is therefore somewhat lower under straw and coir mulching compared with saw dust mulch. This causes soil temperature of a bare soil to be higher than a mulched soil during the day (especially in the afternoon).

Table 2Change in average soil temperature (°C) at different soil depth and time

Ambient Temperature	Soil depth(cm)	08.00	14.00	17.00
No mulch	5	19.4	32	26.8
coir	5	18.8	27.6	25.6
straw	5	18.7	27.7	24.7
Saw dust	5	17.8	27.3	24.3

32°C	Soil depth(cm)	08.00	14.00	17.00
No mulch	5	20.4	32.2	27.8
coir	5	19.8	28.4	24.5
straw	5	19.7	28.6	24.8
Saw dust	5	19.8	28.5	24.3

34°C	Soil depth(cm)	08.00	14.00	17.00
No mulch	5	20.8	33.9	28.1
coir	5	21.7	29.9	25.6
straw	5	22	28.8	24.8
Saw dust	5	23.9	28.6	24.3

Suwon and Judah (1985) reported that soil temperature increased with the use of plastic mulch. The polythene mulches allowed part of the radiation to pass through it but acted as barriers against outgoing thermal radiation. Variability of soil temperature in the upper few cm of the soil was likely due to the type of the mulch (Fortnum et al., 1995; Petrov and Al-Amiri, 1976).

3.1.6 Soil Phosphorus content

Average soil phosphorus among the treatments ranged from 20.9 – 21.6 mg/kg (Figure 06). According to the results there is no significant difference among the mulches. Significant variation has shown between mulches and no mulch condition. The highest Soil phosphorus content was reported from coir dust and saw dust mulched soil in 32 °C temperature condition. In temperature stress (32°C) condition coir dust mulched soil showed the highest soil phosphorus and lowest soil phosphorus content was shown from no mulch condition. Natural organic mulch eventually breaks down and becomes a part of the soil and a source of plant nutrients (Sharma et *al*., 1998).

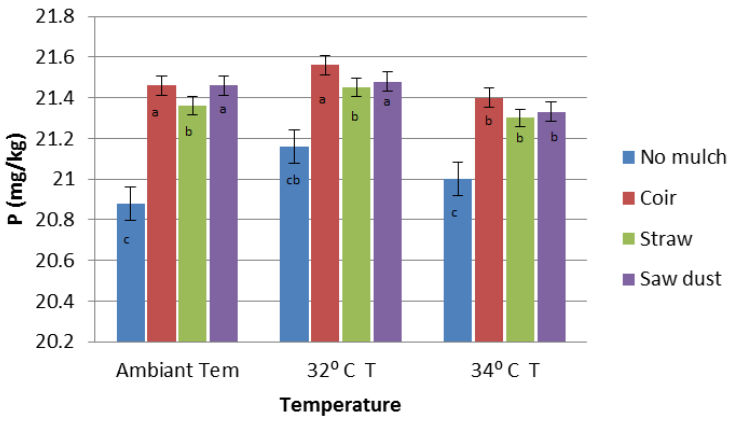

Figure 6 Effect of coir dust, straw and saw dust as mulch on soil Phosphorus content

3.1.7 Soil potassium content

Average Soil potassium content among the treatments ranged from 125-230 ppm (Figure7). According to the results there is no significant difference with temperature. Significant variation has shown between coir dust and no mulch condition. The highest soil potassium content was reported from coir dust mulched treatment followed by saw dust treatment. Tree-based mulches influence soil potassium and plant growth. Growth and fruit yields were associated with K availability in the soil and potassium content proportionally increased with the yield. Sonsteby *et al.*, (2004) established increased amounts of phosphorus and potassium levels in crop leaves in plots mulched with wood chips which agree with the results of this study.

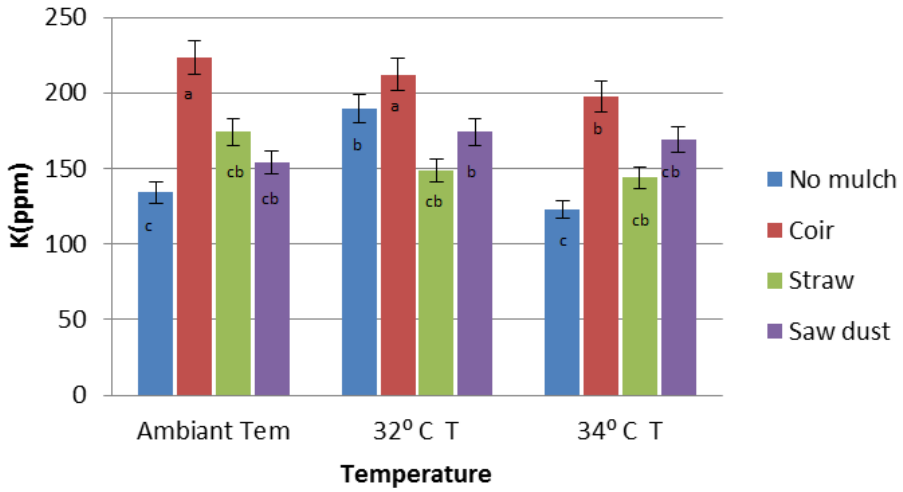

Figure 7 Effect of coir dust, straw and saw dust as mulch on soil potassium content

3.2 Growth and Yield parameters of chili

3.2.1 Plants height

Plant height was measured from 60 days after planting. The plant height varied significantly due to temperatures. Average plant height among the treatments ranged

from 44 -74 cm. Generally, height of the plants maintained at 34°C maximum temperature is significantly higher than that of the others($p<0.05$). Plant height is lower in plants grown in ambient temperature than the 32°Cand 34°C. High temperature induces rapid growth and therefore the plant height is significantly high in plants grown in 34°C maximum temperature poly tunnel which agrees with Ravinder *et al.*, (1997). Further, height of the plants mulched with sawdust was highest followed by coir dust and straw in stressful temperature at 34°C. Plants grown in no mulch condition was lowest in height. The increased plant height in saw dust mulched plants was possibly due to better availability of soil moisture, higher organic matter content and optimum soil temperature.

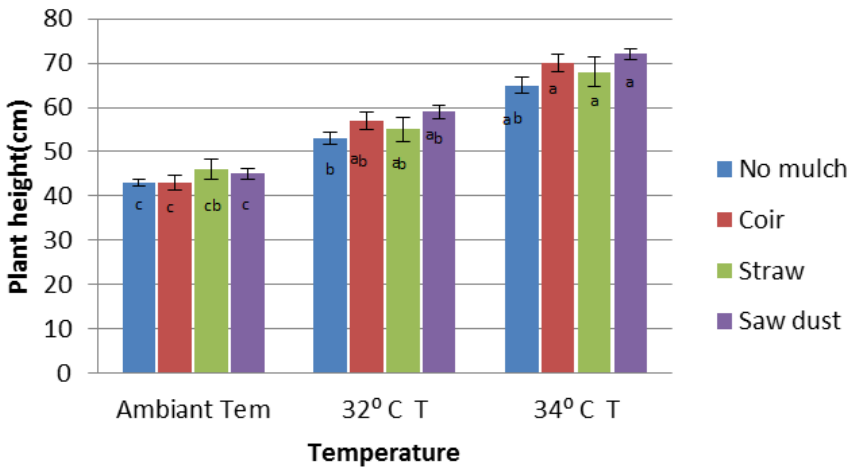

Figure 8Effect of Coir dust, Straw and Saw dust as mulch on average plant height.

3.2.2Pod yield

The fresh fruit yield is the most important character when considering the economic importance of this crop. These results showed that individual mulches effect on yield (Figure 9). Saw dust mulched treatments showed a significantly highest yield comparing with the other mulches ($p<0.05$). Present results are in agreement with Strizaker *et al.*, 1989. Higher air temperatures will also be felt in the soil, where warmer conditions are likely to speed the natural decomposition of organic matter and to increase the rates of other soil processes that affect fertility. The highest number of fruits per plant (315g/plant) was shown at 34°C maximum temperature with sawdust mulch conditions, which is within the recommended yield range for chili in ideal conditions.

Further when temperature exceeds the optimum for biological processes, crops often respond negatively with a steep drop in net growth and yield. But in this study the effect of saw dust mulch has resisted the high temperature stress simulated on chili plants.

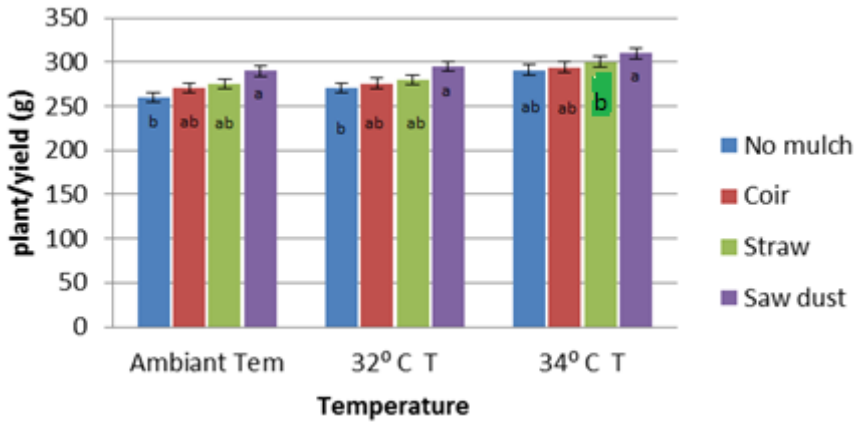

Figure 9Effect of Coir dust, Straw and Saw dust as mulch on average plant yield

Table 3 Mean values of growth, yield and soil parameters of Chili under deferent treatments

	Yield/plant(g)		plant height/cm		soil-pH		Ec(ds/m)		Organic matter		Soil moisture		(K(ppm)		P(mg/kg)	
Treatments	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std
Ambient tem-no mu	260	±5.306	43	±0.63245	6.424	±0.2150	0.0808	±0.0044	3.05	±0.0275	18.2	±0.7483	20.4	±0.3741	20.4	±0.37416
Ambient tem-coir	270	±10.91	45.4	±1.62480	5.608	±0.4253	0.069	±0.0078	3.68	±0.0748	18.444	±0.6308	21.46	±0.2332	21.46	±0.23323
Ambient tem-straw	275	±11.26	44.9	±0.58309	6.328	±0.3893	0.0874	±0.0004	3.2906	±0.0352	18.48	±0.2959	21.36	±0.1854	21.36	±0.18547
Ambient tem-saw dust	290	±11.25	47	±1.26491	6.8	±0.2449	0.0836	±0.0041	3.8	±0.0632	18.58	±0.3919	21.46	±0.28	21.46	±0.28
32 ° c max tem-no mulch	271	±7.684	53	±1.26491	6.046	±0.3460	0.0852	±0.0021	2.606	±0.0332	17.88	±0.5642	21.16	±0.2059	21.16	±0.20591
32 ° c max tem-coir	276	±4.733	57	±1.89736	5.5	±0.3399	0.0761	±0.0003	3.48	±0.0666	19.12	±0.6942	21.56	±0.3382	21.56	±0.33823
32 ° c max tem-straw	280	±2.416	55	±0.63245	6.468	±0.5289	0.0872	±0.0031	3.342	±0.0256	19.14	±0.3257	21.54	±0.2244	21.54	±0.22449
32 ° c max tem-saw dust	295	±3.852	59.2	±1.6	6.26	±0.1452	0.0717	±0.0058	3.31	±0.1622	19.3	±0.2315	21.48	±0.2561	21.48	±0.25612
34 ° c max tem-no mulch	291	±4.323	65	±1.89736	6.194	±0.0761	0.0768	±0.0022	2.562	±0.0810	17.24	±1.0555	21.28	±0.2925	21	±0.29257
34 ° c max tem-coir	294	±5.462	70	±1.89736	5.726	±0.2535	0.07	±0.0008	3.458	±0.0474	19.06	±0.9319	21.72	±0.1166	21.72	±0.11661
34 ° c max tem-straw	300	±1.777	68	±1.26491	6.62	±0.4575	0.071	±0.0032	3.396	±0.1114	18.96	±0.1445	21.4	±0.3741	21.4	±0.37416
34 ° c max tem-saw dust	310	±3.034	72	±1.26491	6.33	±0.145	0.072	±0.0041	3.572	±0.0503	19.06	±0.1577	21.4	±0.2280	21.4	±0.22803

4 CONCLUSIONS

When considering the effect of mulch on soil properties, in sawdust mulch the neutral pH (6-6.5 was maintained even within the stressful temperature at 34°C. Further this pH has improved the decomposition rate and therefore maintained the higher organic matter content. Further the Saw dust mulched soil has the highest electrical conductivity and the highest moisture content as electrical conductivity increases with increased moisture content. Saw dust and coir dust has very good water retention capacity which will be advantageous in drought conditions. Results revealed that sawdust mulch maintained the soil temperature at the range of 28.6°C even the air temperature was maintained at

34°C. By this chili plants were able to maintain their metabolic activities satisfactorily even at stressful temperature.

From the study of Gunawardana *et al.* (2012), it was observed that the interaction effect of the stresses of temperature and water had higher significant impact on growth and yield of the chili production. Gunawardana *et al.(*2012) suggested that the yield reduction of chili due to temperature stress could be overcome by keeping the plant without water stress during growing period.

However the present study results showed that higher temperature stress in natural environment either due to global warming or any other conditions could be minimized by using saw dust mulch as the highest yield (315g/plant – within the recommended yield range) was obtained in sawdust mulched plants in stressful temperature of 34°C. Soil mulching is a sensible strategy to reduce evaporation, accelerate crop development, reduce erosion and assist in weed control. As a consequence of reduced evaporation, soil mulching benefits the conservation of water, particularly in the topsoil. Saw dust and coir dust mulches reduce water evaporation from soil and help maintain stable soil temperature even in stressful temperature. These two mulches could be easily available for farmers therefore the adverse effects on soil due to high temperature stress could be minimized by using mulch such as saw dust or coir dust could ensure food security in Sri Lanka.

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Design of Soil Moisture Sensitive Automatic Drip Irrigation System for Roof Top Gardening

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Abstract-*Agriculture sector is the backbone of Sri Lankan economy and it consistently requires technological advancement. In the past, agriculture is concentrated only in rural areas. Rooftop gardening is becoming popular in highly populated urban areas where land for agriculture is scanty. Usually cement or plastic pots are used to grow plants on rooftops or balconies and the moisture in these pots can be easily dried off since they are subjected to harsh weather conditions such as heavy winds and bright sunlight. Hence, close monitoring and frequent watering are necessary steps to keep the plants alive despite they can be time consuming. Therefore, this study attempted to overcome these problems by introducing* ***a soil moisture sensitive automatic drip irrigation system for roof top cultivation****. The irrigation system consisted of a main control unit, gypsum block sensors, soil moisture sensing device, Electronic Sensor Unit (ESU) to detect GBS signals, Oscillator Unit (OU) to make oscillator waves for GBS, Peripheral Interface Controller Unit (PICU) to detect ESU signals and compare the ESU signals with programmed commands, Power controller Unit (PCU) to control irrigation duration and Rain Detector Unit (RDU) to detect rain weather. This irrigation system was compared with sprinkler bucket (manual) irrigation using threecrops, tomato (Solanum lycopersicum L.), Capsicum (Capsicum annuum L.), Brinjols (Solanum melongena L.). This study shows that an automated system can be developed using the basic knowledge on electronics and using the basic electronic items available in the market in a cost effective manner. The study concludes such an irrigation system could save up to 40% of irrigation water and significantly improve growth and yield of the crops grown on rooftops.*

Key Words: *Automatic irrigation System, Roof top gardens*

Nomenclature

FC - Field Capacity
PWP - Permanent Wilting Point
MCU - Main Controller Unit
ESU - Electronic Sensor Unit
GBS - Gypsum Block Sensors
OMIS - Optimum Moisture Indicator System
IAIS - Irrigation Apply Indicator System
PICU -Peripheral Interface Controller unit
PCU -Power Controller Unit
RDU -Rain Detector Unit
DC -Direct Current
ER -Electrical Resistance
LMIS - Low Moisture Indicator System
IWAS - Irrigation Warning Alarm System
kΩ -Kilo Ohm

1 INTRODUCTION

Rapid urbanization may cause serious environmental destruction finally contributing to the global warming. In urban areas, high night temperature caused by the phenomenon called the heat-island effect may create uncomfortable living conditions for urban population. A practical way to cope this situation is urban greening. However, available space for urban greening is getting limited and a practical way of doing is the rooftop gardening.

Rooftop gardening could significantly reduce heat-island effect (Wong et al,. 2003). In addition vegetation on the roof could also help to reduce dryness in the air through transpiration and to purify the air (Park et al., 2008). Further in developing countries rooftop vegetable gardening could also promote food security by supplying more quantity, variety and the quality to the daily diet while certain instances making it as an income generating activity.

In most of the rooftop gardens, vegetables are grown in pots and the moisture in these pots can be easily dried off since they are subjected to harsh weather conditions such as heavy winds and bright sunlight. Thus water levels of these pots should be closely monitored and maintained at field capacity levels without letting them dry out. Frequent wilting of plants could decrease the productivity and thereby reduce the profitability. Hence watering of plants at adequate levels and correct frequencies are crucial in maintaining a vigorous growth of plants. Uncontrolled frequencies and quantities of watering may also have detrimental effects on the stability of the materials of the rooftop. Further it is a wasting of water leading to an unnecessary cost.

The common practice of watering in the rooftop gardening is the manual watering with a horse pipe or sprinkler buckets. These types of practices are labor intensive, time consuming and costly due to unnecessary wastage of water. Drip irrigation on the other hand could increase the water use efficiency thereby saving the water[1], increase the yield and the labor requirement. Therefore this study was to design an automatic drip irrigation system using available electronic devices in the local market and to find the applicability of the automatic irrigation system with pot experiment.

2 METHODOLOGY

Automated irrigation systems have been developed and used for several years using different devices. Fangmier *et al.* (1990) have developed an automated irrigation system using plant and soil sensors. Their system consisted of two infrared thermometers, an aspirated psychrometer, four soil resistance blocks, a data logger, a solar panel, and a 12 V-DC battery. In this system the data logger was programmed to collect measurements from the sensors and determine the irrigation requirement. The study indicated that the hardware performed well but that inadequate criteria for determining the crop water stress index prevented the system from automatically starting irrigation. Later Araya *et al.* (1991) have designed an automated drip irrigation system for Chilean conditions

[1] This is very significant in rooftop gardening since expensive tap water is being used.

based on the use of a low-cost personal computer. Wanjura *et al.* (1991) have also developed and tested an automated irrigation system for cotton. It consisted of sensors located within irrigation scheduling treatments and a PC which controlled individual irrigation lines through MS-DOS operations. More recently, Testezlaf *et al.* (1997) developed an automated irrigation computer control system for management of greenhouse container plants. This system consisted of soil moisture sensors, a hardware input/output interface, a computer with a software interface, and actuators. Koc *et al.* (1997) and Ribeiro *et al.* (1998) used the Fuzzy Logic System in automated irrigation and found that it provides a very useful approach to simplify the automation process. Based on the above facts the following irrigation system was developed.

2.1 Irrigation system

The automatic drip irrigation system used in the study consisted of Main Control Unit (MCU), Gypsum Block Sensors (GBS) as the soil moisture sensing devices, Electronic Sensor Unit (ESU) to detect GBS signals, Oscillator Unit (OU) to make oscillator waves for GBS, Peripheral Interface Controller Unit (PICU) to detect ESU signals and compare the ESU signals with programmed commands, Power controller Unit (PCU) to control irrigation duration and Rain Detector Unit (RDU) to detect rain weather. The irrigation system was arranged as three zones demarcating one zone for each crop as given in Figure 2.1. The system was also supported with optimum and low moisture indicator systems for each zone, Irrigation application and warning alarms and emergency system bypass valves. The system was controlled by solenoid valves.

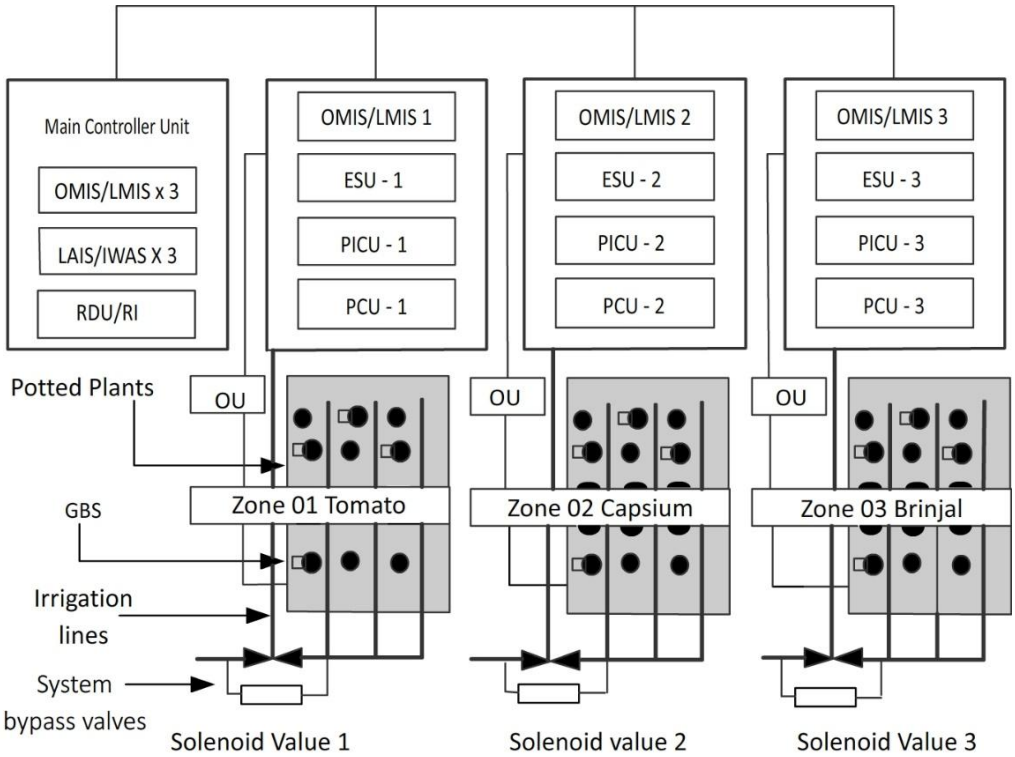

Figure 1 Schematics of the Automatic irrigation system

Tomato (*Solanum lycopersicum*L.), Capsicum (*Capsicum annuum*L.), and Brinjols (*Solanum melongena*L.) were used in the experiment and verities used were Padma, CA-8 and Amanda respectively. Thirty plants from each crop i.e. in each zone were used in the experiments. Each zone was divided into two sub zones to apply two different watering systems used as the treatments in the experiment (TR1=Manual irrigation and TR2=Automatic irrigation).

The experiment was conducted at the rooftop garden of the Science and Technology building of the Open University of Sri Lanka, Nawala, Nugegoda.

2.2 How the system works

The experimental results shows the FC and the PWP of the potted media are 28.53% and 17.15% respectively. When soil moisture level reached to midpoint of FC and PWP of potted media, which is around 23%, the electrical resistance values of the GBS increase with soil moisture depletion and it reaches to the set point. The set point is the electrical resistance of GBS at the required moisture level, which is 20 kΩ. The ESU detects when the moisture level reaches to the set point value according to the electrical resistance.

ESU detects six GBS signals and directs them to PICU. The PICU analyses these six signals with operating instructions programmed on microcontroller. If the signals are matching with the working instructions, PICU generates a signal and it sends to the Power controller unit (PCU).

The PCU is then receives PICU signal and turn on the solenoid valves and also turn off after specific time duration. This time duration can be adjusted from two seconds to a maximum of three hours, which mainly depends on the size of the pot, infiltration characteristics, water flow rate and the soil type of the potting media. When raining, the irrigation system is totally cut off by rain detector unit.

2.3 Determination of moisture content at which irrigation has to be induced

The irrigation system is automatically activated when soil moisture of a pot reduced to the 50% of the field capacity (FC). Moisture content at the FC was measured using the gravimetric method and pressure plate apparatus. Then amount of moisture at the permanent wilting point (PWP) was calculated by oven drying the soil and finally the soil moisture content at 50% of the FC is calculated[2]. Amount of water needed to bring the soil media to 50% of FC was back calculated after adding that amount of water and allowing time settle it down the resistance at 50% FC was then determined. This was repeated for six times to obtain the accurate Electrical Resistance (ER) value corresponding to the 50% FC and the average values are given in Table 1.

[2] $Soil\ Moisture\ Content\ at\ 50\%\ FC = \frac{Moisture\ content\ at\ FC - Moisture\ Content\ at\ PWP}{50}\ \%$

Table 1 Gypsum block resistant values for gravimetric method and pressure plate soil moisture testing methods

Method	Moisture content at the midpoint of FC and PWP	ER of GBS (R_{Test}) kΩ
Gravimetric Method	22.98%	19.7 (Approximately)
Pressure Plate Method	22.83%	20.3 (Approximately)
Average	22.90%	20

The amount of water needed to bring it into 50% of the field capacity was calculated depending on the amount of weight of the potting media and the volume of the pot.

2.4 Pot experiment

Two irrigation systems (TR1 = Manual irrigation; TR2 = Automatic Irrigation) and three crops (Tomato, Capsicum and Brinjal) were used in the pot experiment. The treatments (TR1 and TR2) were arranged in a Complete Randomized Design (CRD) for each crop with three replicates. Amount of water irrigated through micro irrigation was measured at randomly selected pots at each zone. Then number of times the system operates was observed and the amount of water needed per day for irrigating each crop was calculated. Then the amount of water needed for each crop month was extrapolated. Amount of water needed to water the plants for crop was also recorded.

2.5 Measurements

2.5.1 Water requirement

Growth and yield measurements

Plant height and stem girth at weekly intervals, days to first flowering and yield were recorded.

3. RESULTS & DISCUSSION

3.1 Impacts of two irrigation methods on water usage, plant growth and yield

3.1.1 Total water usage

It was observed that the amount of water irrigated through the automatic irrigation system did not vary significantly among crop species. Since the same amount of water applied for each plot manually, calculation of total water requirement was done based on average values of all three crops. The daily and monthly water requirements for two different treatments are given in Fig 3.1. The weekly and monthly water requirement in the automatic irrigation system is significantly lower than that for manual watering. It is calculated that the irrigation efficiency is 40% higher in automatic irrigation than the manual sprinkler bucket irrigation. This may be attributed to the application of water at right quantities when only it is exactly needed in the automatic system.

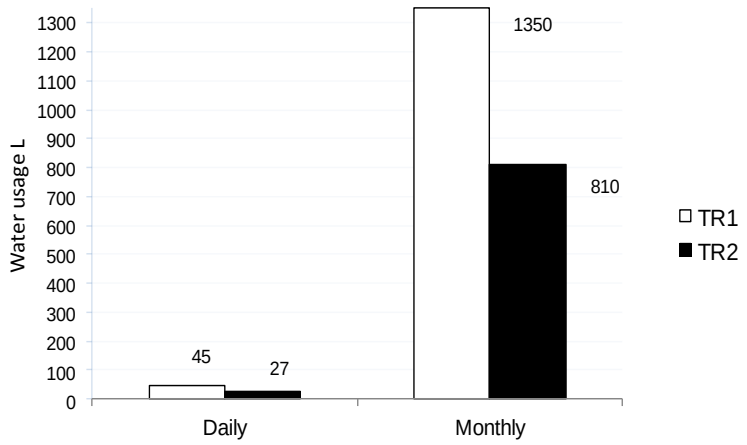

Figure 2 Water requirements of different irrigation systems

3.2 Effect of automatic irrigation on growth of plants

Fig 3.2shows the impact of two different irrigation methods on plant height measured at weekly intervals of the three crops. Automatically irrigated plants showed a better growth at the latter stages of growth and it was significantly higher in tomato and capsicum. In contrast even though stem girth also showed a better growth in automatically irrigated plants at the later stages of growth, significantly higher growth was only observed in tomatoes (Fig 3.3). The higher growth in automatically irrigated plants may be attributed to the optimal growth conditions provided through higher irrigation efficiency. Thus by using automated irrigation system, significant amount of water can be saved while minimizing the watering time and effort.

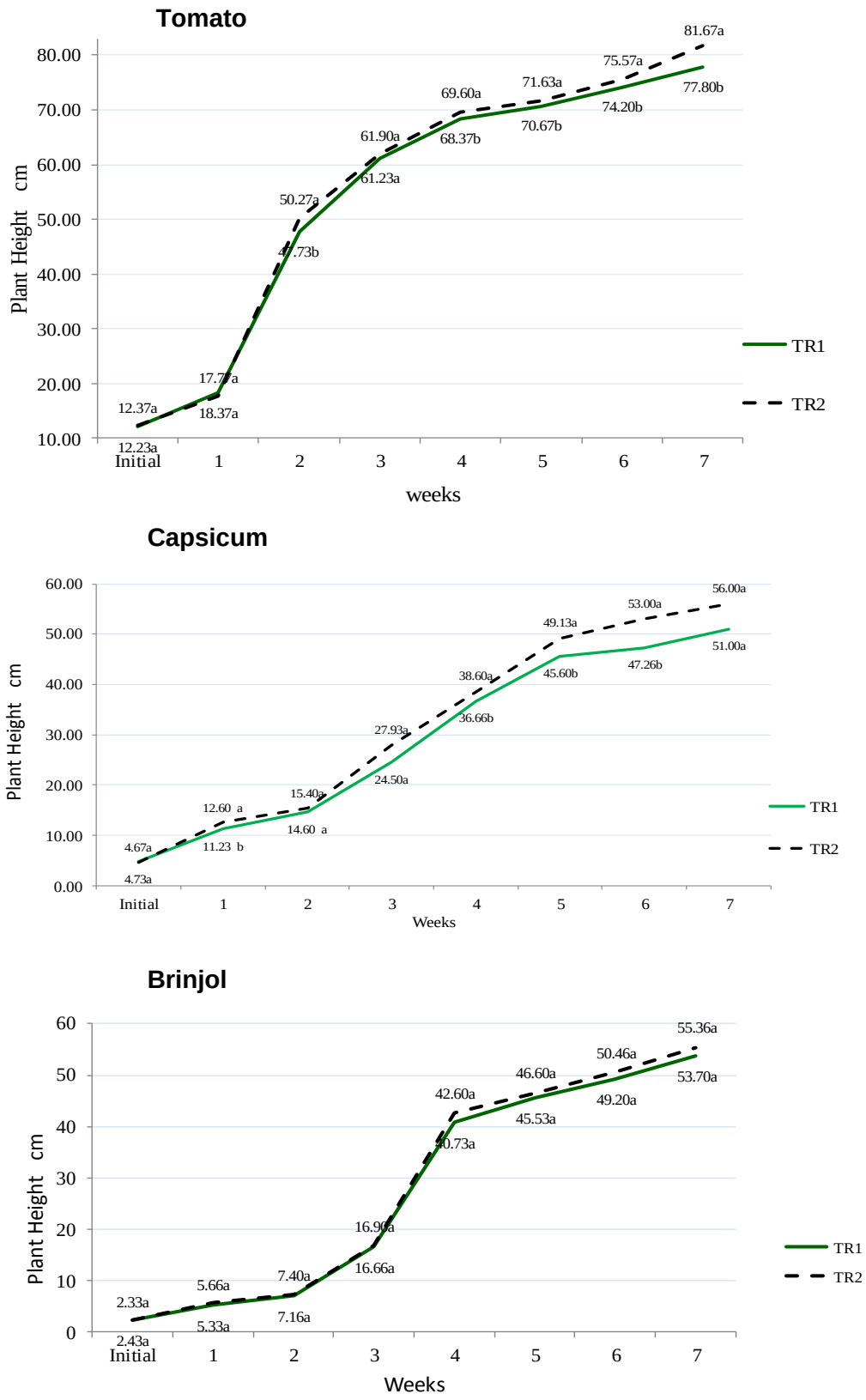

Figure 3 Effect of two irrigation systems on plant height of different crops

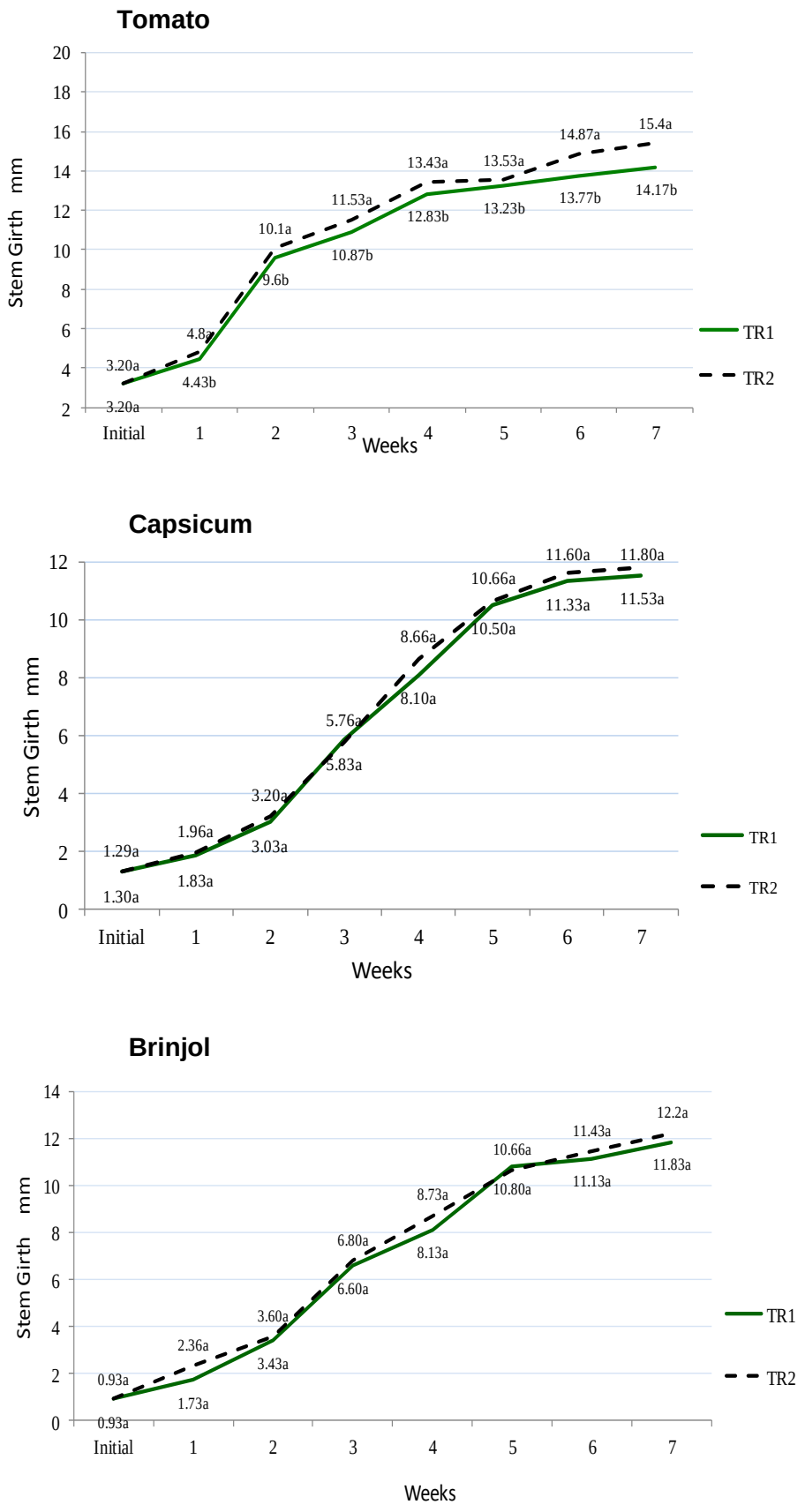

Figure 4 Effect of two irrigation systems on plant girth of different crops

Figure 5 depicts the effect of two irrigation systems on number of days to flowering of three crops. In consistence with the growth of the plants, all three species showed early maturity when they were treated with automatic irrigation. However, the treatments were not significant.

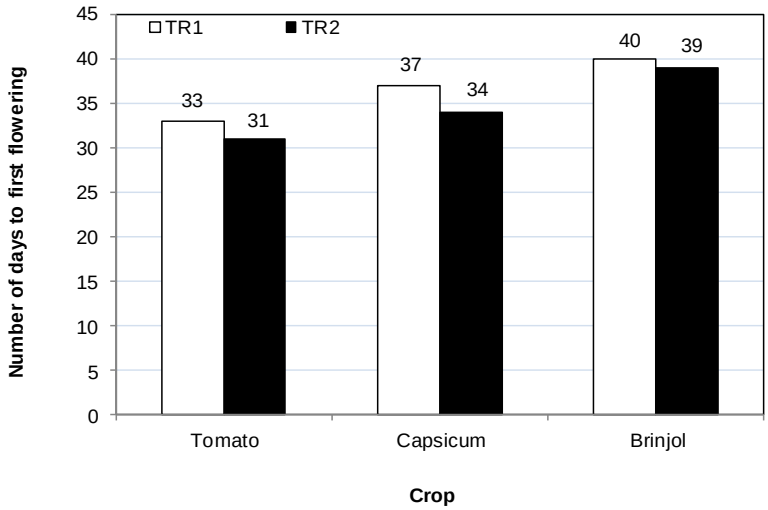

Figure 5 Number of days to first flowering as affected by two irrigation systems

3.3 Crop yield

Yield of each sub plot was recorded and the average yield of each treatment was calculated (Figure 6). The crops showed higher yields in automatic irrigation system. It showed a significant difference in crop yield in manual and automatic irrigation for tomato. The automatic drip irrigation provides better condition for crop growth.

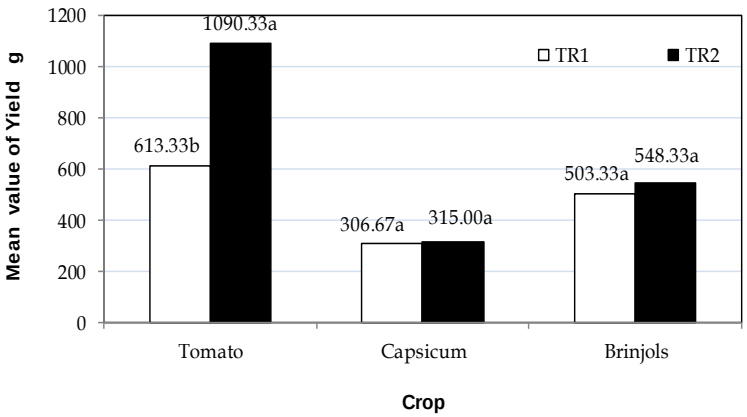

Figure 6Effect of automatic irrigation on crop yield

Note- Means with the same letter are not significantly different at $p = 0.05$

4 CONCLUSIONS

This study concludes that automated irrigation system can be set up with a basic knowledge on electrical circuits and agriculture using the basic electronic items. These systems not only reduce the cost of water (in general we use pipe born water in rooftop gardening) but also the time required for watering rooftop gardens. These systems can increase the irrigation efficiency and water the plants when only required and at right dosages. Subsequently plant growth can be improved thereby increasing the final yield of the crops.

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Removal of Nutrients from Urban Water by Engineered Constructed Wetland with Bio-Geo Filter and Biotope

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Abstract - *The aim of this research was to introduce Bio Geo Filter – an engineered constructed wetland, on removal of nutrients of polluted urban stream water by using plants and geo materials which can be affordable in low income countries. Selected physical and chemical parameters of urban water were investigated during dry and wet seasons while monitoring the stream discharges with rainfall to obtain the concentrations of pollutants. According to topography and geotechnical properties of soil layers, and pollutant loads of the urban stream an ecofriendly, economical, engineered solution namely Bio Geo Filter (BGF) and Biotope was proposed. The entire treatment system was designed to withstand during possible flash flood flows during storm events. Biotope was established with tropical and terrestrial plants while the aquatic plants with high economic value were recommended for the BGF. A polishing pond at the downstream of the BGF was employed to visualize treatment efficiency before water enters to the Urban Canal. Biotope with uniform environmental conditions provides a living place for a specific assemblage of plants and animals was established on the stream embankments.*

Keywords*: engineered constructed wetland, Bio-Geo Filter, Biotope, pollutant load, nutrient removal, urban water*

Nomenclature

As - Surface area of wetland (m^2)
L - Length of the wetland cell (m)
W - Width of the wetland cell (m)
Q - Average flow through wetland (m^3/d)
C_e - Effluent pollutant concentration (mg/l)
C_o-Influent pollutant concentration (mg/l)
K_T - Temperature-dependent first-order reaction rate Constant (d^{-1})
y - Depth of water in the wetland cell (m)
n - Porosity

Greek Letters

σ -Stefan Boltzmann Constant
ε_{app} - Apparent thermal emittance

Subscripts

e - Effluent
o - Influent
s - Surface
$_T$- Temperature

1 INTRODUCTION

The growing population and an increase of industrialization and agricultural production in numerous countries such as Sri Lanka require more and more water of adequate quality. In many regions there is a lack of surface water and severe water contamination is to be found (Ileperuma, 2000). Therefore, it is of high priority to take into consideration all the proved water techniques that could help to reduce the existing disaster of water pollution.

Nutrient enrichment of natural water system due to wastewater disposal is a critical issue in Sri Lanka. The Diyawanna Oya water system which consists of Kirulapone Canal is an important surface water source in Colombo metropolitan region is currently getting polluted due to haphazard wastewater disposal practices of surrounding communities. One of the streams, which connect to Kirulapone Canal, flows across the Open University of Sri Lanka (OUSL) premises, gives unpleasant image to the OUSL, as it carries grey water of nearby community as shown in Fig 1 and Fig 2. The government of Sri Lanka has been proposed to use the Diyawanna Oya for transportation (Times online, 2011). However with the present condition it is rather questionable and therefore, the water has to be clean and free from significant pollutants as well as undesirable colour or odour.

Figure 1 Location map and the catchment of the OUSL stream

The objective of this research is to establish a Bio Geo Filter (BGF) and Biotope on the stream bed and at the embankments of the stream in order to purify the stream water by removing nutrients before flowing into the Diyawanna water system. In addition this research study would play an important role in the development of the city and an educational model to enhance public attention on clean and pleasant environment.

1.1Study Area

The stream involved in this research is located in between the Media House and Exam Hall-03 at the main campus of The Open University of Sri Lanka at Nawala, Nugegoda in Colombo District. The approximate length of the stream is 82 meters and the stream water originated from a low income community about 150 populations in adjacent lands of the OUSL premises. It is recorded that the influent contains the grey water such as wastes from bathrooms, kitchens and black water from toilets.

(a) **(b)**

Figure 2The view of the urban stream (a) Stream covered with aquatic plants (b) Stream and Culvert at the OUSL premises

2 RATIONALE

BGF represents the combination of Bio and Geo materials for the filtration (Jayasekara, 2008). The BGF design is based on **Free Water Surface (FWS) Constructed Wetland.** The said technology of wastewater purification has many advantageous over the other methods used in Sri Lanka. Biotope is a distinct set of environmental conditions that supports a particular ecological community of flora and fauna provides an aesthetically pleasant environment. This research is twofold focusing to propose water purification system for Kirulapone Canal flowing across the OUSL to Diyawanna water body using Bio Geo Filter Ditches and to develop a Biotope at the embankments.

2.1 Stream pollution and related impacts

The stream pollution can be occurred due to disposal of wastes into streams or any water body. Eutrophication and biomagnifications are the most critical issues that may occur due to stream pollution. Hence, a special care should be taken to avoid or minimize these to save the nature and to provide a healthy life of nation and endorse the importance of avoiding pollution of streams is very obvious.

There are various methods available to treat wastewater. Most of those require separate units such as treatment plants for the treatment process. Those units require continuous maintenance and involve high initial and operational costs (Reed *et al*, 1995; Jayasekara, 2008). Therefore, such methods are inappropriate to treat polluted streams. **Constructed wetland is one of the low cost most appropriate solutions used all over the world which can be applied for polluted streams (Reed *et al*, 1995) having continuous flow with nondestructive surrounding.**

Constructed wetlands purify wastewater for improving water quality (Moshiri, 1993) and support wildlife habitat. It can also be a cost-effective and technically feasible approach to treat wastewater. Construction wetlands are often less expensive to build than traditional wastewater treatment options, having low operating and maintenance expenses and can handle fluctuating water flows. Additionally, it provides aesthetically pleasing environment and reduces or eliminates odors associated with wastewater (Kadlec & Knight, 2004).

Aquatic plants in the constructed wetland systems play the key role of purifying wastewater, entered to the system (Campbell & Ogden, 1999). A complex variety of physical, chemical and biological processes, including sedimentation, filtration, aerobic degradation, anaerobic degradation, nitrification, de-nitrification, adsorption and precipitation reactions are contributed to this purification process with microorganisms living on and around the plants.

2.2 Bio–Geo Filter (BGF)

The Bio–Geo Filter (BGF) is based on **Subsurface Flow (SF) Constructed Wetlands** and introduced as an ideal treatment system that suits for small waste capacities and for domestic installation with a combination of bio and geo materials namely Bio -Geo Filter (BGF) ditches. Cattail, duck weed, reed and bulrush are prominent aquatic plants, which are widely used for wetland cells in European countries, (Reed *et al*, 1995). Abe (2001) showed that papyrus, kenaf, crysanthemum, salvia and tomato can also be used as Bio-Geo filter vegetation.

A pilot scale Bio-Geo Filter ditches has been established at the Open University premises to demonstrate the potential for treatment of domestic wastewater using geo materials and plants. Selected bed filter materials and useful terrestrial plant species such as African merigold, canas, papyrus and reeds were employed for nutrient removal. This pilot-scale BGF containing laterite (kabook) stones with its rich composition of iron and aluminium, has been achieved nearly 100% removal of phosphorus (Jayasekara, 2008).

The pilot scale BGF shows the excellent pollutant removal efficiencies for NH_4^+, NO_3^-, and NO_2^-. It was recorded that pollutant removal efficiencies are generally high in the BGF showing 90% removal efficiency for NH_4^+ while the removal of $NO_3^-$and $NO_2^-$is around 100%. The BGF significantly removes TDS, conductivity and salinity and further the COD and turbidity reduction was above 90%. Ditches with papyrus and reed help to control pH before discharge. The plant species, which provide economic and aesthetically appealing aspects, are engaged to produce renewable energy in further step of this study (Liyanage *et al,* 2010).

2.3 Biotope

Biotope is an area of uniform environmental conditions providing a living place for a specific assemblage of plants and animals. Biotope is almost synonymous with the term habitat, while the subject of a habitat is a species or a population; the subject of a biotope is a biological community. Although the term "biotope" is considered to be a technical word with respect to ecology, in recent years the term is more generally used in administrative and civic activities.

3 METHODOLOGY

Water quality parameters such as Phosphate, Nitrate, Ammonia, COD, and pH, Total Dissolved Solids (TDS), Salinity and Conductivity of the wastewater were tested. Phosphate, Nitrate and Ammonia are tested using Spectrophotometer (Hatch potable type) while pH, Total Dissolved Solids (TDS), Salinity and Conductivity were obtained using pH meter. The COD test was carried out by Open Reflux Method. The maximum and minimum discharge of wastewater in the stream was measured in wet and dry seasons respectively using a current meter of model Electromagnetic Flow Meter 801. Using the flow velocity readings given by the current meter relevant discharge was calculated. The rainfall of the project area was measured for each 10 minutes interval through the months October, November and December of the year 2010 with "Watch Dog-Spec 8 Pro" Rainfall Gauge. The rainfall gauge was placed at the roof top of a building nearby place to the stream.

The leveling survey was carried out to find the gradient of the stream and the topographical features of the area where the treatment unit is to be constructed. Longitudinal sections of stream and the cross section at 4m change where the dam is to be constructed are drawn. The geotechnical Investigation was carried out to identify soil condition of the area using borehole records such as soil types, thickness, SPTN values, of soil layers.

The collection pond was designed to control the flow of wastewater prior to enter to the BGF minimizing fluctuation of the stream velocity. The dam was designed by considering the hydraulic, geotechnical and structural design procedures. The hydraulic design of the collection pond was done based on the required retention period to be fulfilled the effluent quality according to the regulations stipulated by the Central Environmental Authority, Sri Lanka. The depth of the dam to be driven from the dredge level was calculated following cantilevered sheet pile design while the dam was designed by using cantilevered retaining wall design. The reinforcement calculation was done with respect to the critical bending moments at the base and wall of the dam. The design was completed by checking the satisfaction for the required conditions. The cost estimation was done based on the current rates of materials.

3.1 Design and Establishment of BGF & Biotope

The system was worked out to suit the topographical condition and flow rate and pollutant concentrations of wastewater. The BGF design was done by using the design concepts of **Free Water Surface (FWS) Constructed Wetlands. The surface area, number of cells and the depth of water were considered as the most important facts which were focused in the design.**

The design procedure for BOD removal of FWS constructed wetland is given by equations 1, 2 and 3.

Surface area

The surface area of the wetland can be determined by using Eqn-1 (Reed et al, 1995). Since the BGF design is based on FWS Constructed Wetland, the same equation is used in BGF design.

$$A_s = LW = \frac{Q(lnC_o - lnC_e)}{K_{Tyn}} \quad (1)$$

Reaction rate constant

Temperature dependent first order reaction rate constant, K_T was found by the Equation 2.

$$K_T = K_{20}(1.1)^{(T-20)} \quad (2)$$

$$K_{20} = 1.104d^{-1}$$

Hydraulic retention time

The hydraulic residence time in BGF was calculated by the Equation 3,

$$t = \frac{LWyn}{Q} \quad (3)$$

The suitable plants for the BGF and Biotope were identified according to the condition of the stream and the efficiency of pollutant removal of the plant species. Planting for Biotope was undergone with selected plant species on the embankments of the stream to improve the aesthetic view at the stream embankments.

3.2 Plants for BGF

Generally, emergent plants, those rooted in the soil or granular support medium that emerge or penetrate the water surface are used in wetland systems. The plants species used most frequently in constructed wetlands include Cattails, Reeds, Carex, Bulrushes and Papyrus. Therefore these species and some more locally available plants with Habarala which is readily available at the stream were used in BGF in the stream. Suitable plants for Biotope were identified and the appropriate plant species for stream embankment for Biotope were listed. First stage of planting on the embankment of the stream for Biotope was done with the plants given in Table 1. These plants were selected by considering the condition of the stream area and to provide an aesthetically pleasant view.

Table 1 The list of plant species for Biotope

Common Name	Botanical Name
Murutha	Lagerstroemia speciosa
Kumbuk	Terminalia Arjuna
Bamboo varieties	Bambusa vulgaris Ochlandra stridula Bambusa multiplex
Wel kaduru	Cerbera manghas
Thimbiri	Diospyras malabarica
Girithilla	Argyreia populifolia
Wild Lilies (White and green)	Anthurium sp.
Sooriya	Thespesia populnea
Walbeli	Hibiscus tiliaceus
Watakeiya	Pandanus latifolius
Diya Hawariya	Blyxa aubereei
Diya Koodalu	Impatiens sp.
Diya Meneriya	Commelina benghalensis
Diya Mudilla	Barringtonia asiatica
Kekatiya	Aponogeton crispus
Diya Kaduru	Cerbera manghas
Kelani Tissa	Tecoma stans
Koboleela	Bauhinia variegata
Batakirilla	Erythroxylum moonii
Kahapethan	Bauhinia tomentosa
Goda Kaduru	Strychnos nux-vomica
Thun Iriya	Horsfieldia iriya
Thebu	Costus speciosus
Nelun	Nelumbo nucifera
Ma-Nelum	Nymphaea lotus
Olu	Nymphaea pubescens
Nil Manel	Nymphaea Stelleta
Kumudu	Nymphoides indica

Since the Phosphorous concentration of the stream is higher than the stipulated values, the possibility of phosphorous removal also considered in BGF design. It is found that "Kabook" (a form of Laterite) is capable of removing phosphorous (Jayasekara, 2008; Liyanage *et al*, 2009). Therefore, "Kabook" was selected as the bed material for BGF with the experimental proof on phosphate removal efficiency of "Kabook".

3.3 Polishing Pond

The polishing pond was proposed to establish at the downstream of the BGF with a pleasant view to visualize the condition of treated water before it enters to the Kirulapone Canal. Flora and Fauna are supposed to introduce into the pond as performance indicators to evaluate the success of the treatment process.

3.4The Catchment Area

The catchment area was identified by field observation at the rain due to unavailability of micro catchment contour maps. Fig 1 shows the micro catchment of OUSL stream, which carries the grey water of the adjacent low-income community.

3.5Phosphate removal

Several tests were performed to investigate the applicability of "*kabook*" as the bed material in the BGF. Retention time of the BGF cells was taking in to consideration when designing the experiments for phosphate removal efficiency of *kabook*. Kabook was kept in the water samples with different phosphate concentrations and sampling was done at 10 minutes intervals. Since the retention time of one BGF cell is 20 minutes, tests were carried out to check the efficiency of *kabook* for 20 minutes of retention as well.

4 RESULTS

Selected water quality parameters of the stream in dry and wet season were measured and are given in Table 2. COD was measured only in dry season and recorded as 58 mg/l. This is extremely lower than the stipulated values by the CEA and therefore no specific treatment was designed for COD.

Table 2 Water quality parameters of the stream

Water quality parameter	Date			
	Dry season			Wet season
	8/2/2010	17/2/2010	23/2/2010	5/5/2010
Conductivity (µs/cm)	628	528	687	467
Salinity (g/l)	0.5	0.5	0.5	0.5
TDS (mg/l)	374	319	413	280
Ammonia-N (mg/l)	9.6	7.3	17.1	2
Phosphate (mg/l)	5.7	4	8.9	0.9
pH	6.73	6.93	7.17	6.6

The rainfall of the study area was measured for each 10 minutes interval through the year 2010.The maximum rainfall recorded was 432.2 mm on 10th of November 2010 (not shown) when the whole area has flooded. This is the highest rainfall occurred for a day in the year. According to the records from Met Department, a closer value to this rainfall was recorded in 1992 that is about 18 years ago. Fig. 3 shows the daily rainfall records during January to July in 2010 in study area. It also indicates the sampling time during dry and wet seasons.

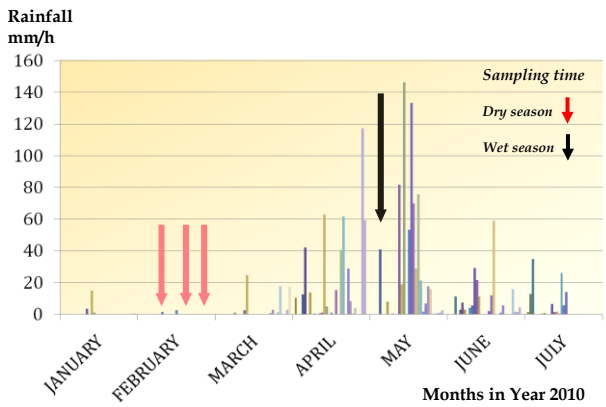

Figure 3Daily rainfall variations of the study area from January to July in 2010

Table 3Phosphate removal efficiency of Kabook with time

Retention time (Minutes)	Phosphate (mg/L)	Removal efficiency (%) *(Cumulative)*
0	4.5	0
10	3.05	67.7
20	2.15	47.7
30	1.4	31.1
50	1	22.2
60	0.82	18

4.3 Purification System

The purification system was proposed for dry flow with high pollution concentrations. Hydraulic design was done using Equations 1-3 and obtained the capacity of the collection pond which was 15.4 m^3. It is assumed that wet season treatment does not require as wastewater dilutes by rainwater. Further system allows overflowing during

flash flows without damaging the treatment system. The average flow rate in dry season is 5.5 l/s. Hence the retention time of the collection pond is limited for 47 minutes. Lay out of the proposed system is shown in the Figure 4.

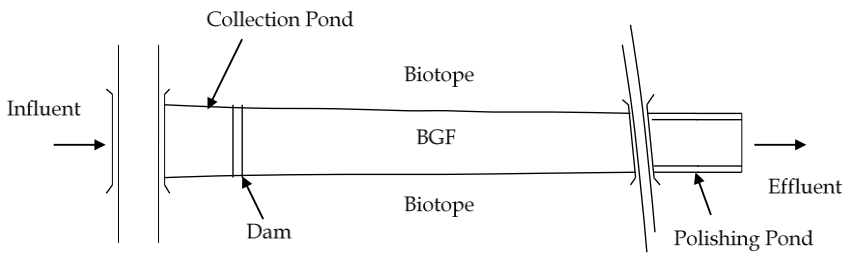

Figure 4 Schematic diagram of the proposed purification system

The waste stream enters to the OUSL premises and flow through culvert across the road. The proposed treatment system inlet is located at the culvert exit. Since the area is narrow stripe with peat soil, the design of collection pond involves hydraulic design, geotechnical design and structural design.

4.3.1 Hydraulic Design

The average flow of the stream in dry season i.e. 475 m^3/d was considered for hydraulic design. Based on the equations given, the dimensions of the collection pond for treating wastewater was estimated as length, width, and depth was estimated as 4m, 3.85m and 1m respectively. The capacity of the collection pond is 15.4 m^3while the retention time provided is 47 minutes. The BGF was designed with three cells of each with 3m x 21m x 0.2m in dimensions and 189m^2 of total surface area. The detail of the hydraulic design is given in Fig.5.

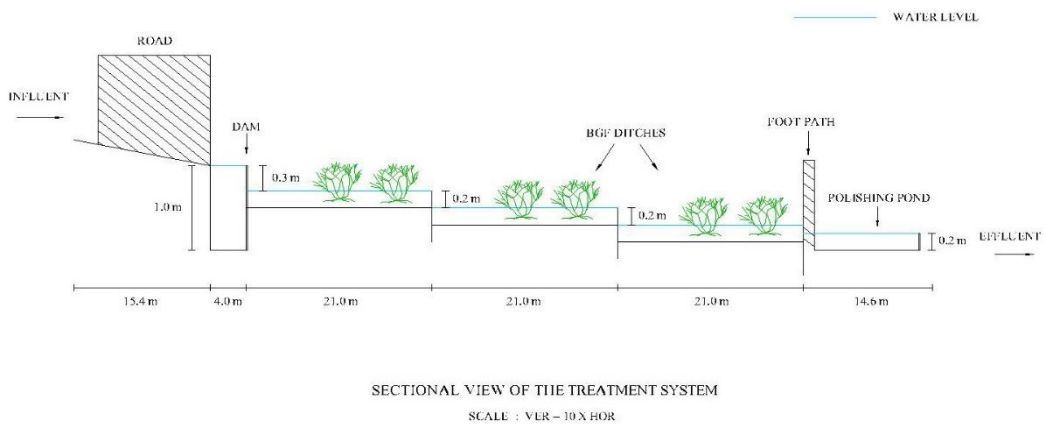

Figure 5 The sectional view of the BGF cells and polishing pond

4.3.2 Geotechnical Design

According to the borehole details, the surface soil goes up to -2.5 m from the ground level and then the peat soil exists from -2.5 m to -4.75 m. The groundwater table exists at -0.8 m from the surface level at the study area. Considering the soils conditions, for the stability of the proposed water retaining structure, geotechnical design was carried out to make sure the dam is stable in the existing soil condition. The depth of the dam to be driven below the dredge level is found by using the concept of Cantilevered Sheet Pile design. The calculations are given below. Fig. 6 shows the levels of proposed dam and existing soil layers. For safety measures it was assumed that the stream bed level and the bottom level of collection pond are same. Determination of extended length is done by Descans Formula, and the depth of the dam from the bottom level of the collection pond was taken as 1.3 m.

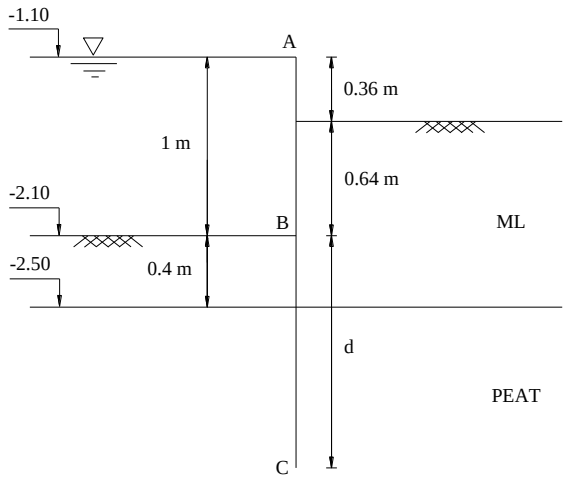

Figure6 The levels of proposed dam and existing soil layers

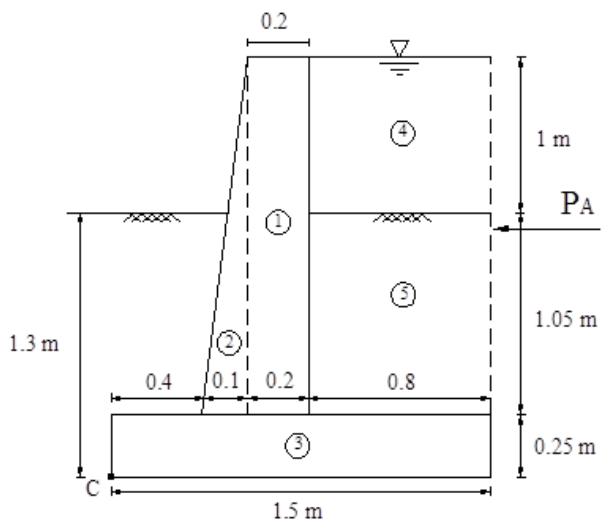

Figure 7 Diagram of dam for designing

4.3.3 Structural Design

The design of dam was done by using the concept of Cantilever Retaining Wall. The finalized dimensions of dam for structural design are given in the Fig.7 while reinforcement details are given in Fig.8.

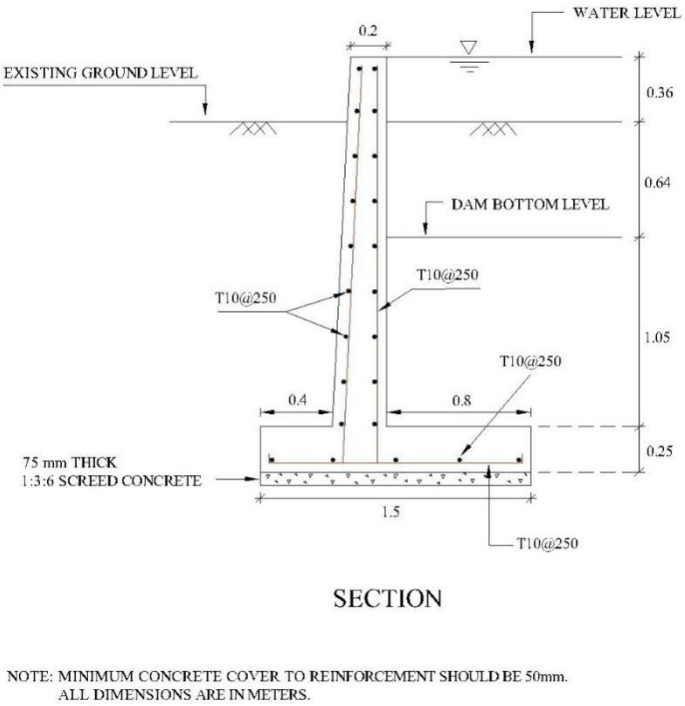

Figure 8Reinforcement details of the proposed dam

4.4 Cost estimation

The peat layer of 2.35m thick was found just 0.4m below the bottom level of the proposed collection pond. Therefore, to carry out the construction, the peat layer supposed to be removed and that should be replaced by quarry dust. Nevertheless that method is costly and to reduce the project cost, two adjustments were carried out: (1) Instead of removing entire peat layer, only 150mm thick peat below the footing to be removed and replaced by quarry dust. (2) Width of the footing to be increased from 1.5m to 2m to reduce the bearing pressure.

5 DISCUSSION

The test results show that some of the pollutants of the wastewater exceed permissible levels mostly during dry season. The levels of phosphate and BOD in dry season were drawn special attention as they lie over the permissible level stipulated by the CEA that is 5mg/l and 30 mg/l respectively. Since phosphate is one of the causes of eutrophication, it may effects the ecosystem of the Kirulapone Canal and also may cause adverse effects

even in the marine ecosystem of sea. The maximum BOD observed was 36 mg/l where the permissible level is <30 mg/l.

Generally stream water purification systems are hardly ever practiced in the word due to impracticality. Instead source protection applies through conventional wastewater treatment methods that involves three stages treatment such as primary, secondary and the disinfection which involves high initial and maintenance cost, more frequent maintenance; artificial chemicals etc. The grey water generated due to the malfunction of the existing treatment system and also due to wastewater generation through small commercial spots such as cycle repairing shops, boutiques. Focusing on above factors an engineered constructed wetland was proposed as the ideal solution to purify urban stream water.

The proposed purification system is with BGF which based on FWS constructed wetland. From the literature survey, it is evident that FWS constructed wetland is an efficient natural wastewater treatment method mostly used in United States, Europe (Arceilvala & Asolekar, 2007; Reed *et al*, 1995) and Australia (Vymazal & Kropfelova, 2008). It is capable of removing most of the similar pollutant found in the wastewater of the stream as well (Reed *et al*, 1995). Though this method requires large area for high performance, the BGF design was successfully done to achieve the required removal efficiency according to the pollutant concentrations and flow of the stream. Therefore, this treatment system was designed with adequate performance, low cost and environmental friendly manner which extremely suit even as educational model at the University.

5.1The Collection Pond

This unit was designed to control the varying flow and to reduce the pollutant level to some extent prior to enter the BGF. According to the space available, the unit was designed to have 45 minute of retention time for dry season flow. Rao & Datta, (1987) recorded that since the water retain in this pond is in aerobic condition, the water look reasonably clean and are free from odour. Therefore, it is expected to remove odour as the pond is aerated by allowing water falls into the pond continuously.

5.2The BGF

The aquatic plants and the bed material are the two of main components of BGF. The most appropriate aquatic plants and bed material were selected for the better performance of BGF.

The plants species used most frequently in constructed wetlands include Cattails, Reeds, Carex, Bulrushes and Papyrus (Jayasekara, 2008). Therefore, these species and some more locally available plants such as Gal ehi pan, Thunhiriya pan, Havan pan, Thela hiriya and Welhiriya with Habarala which is already available on the stream are selected as aquatic plants in BGF. Nevertheless detailed analyses of the performances of locally available aquatic plants are under experiment and are not readily available.

Most commonly used bed materials in constructed wetlands are gravel, coarse aggregates and sand (Arceilvala & Asolekar, 2007; Reed *et al*, 1995; Moshiri, 1993). In addition several locally available materials have been used in Japan (Abe, 2001). The expected outcome from the bed material is to reduce the pollutant level and to support the vegetation growth. By considering these two factors and the availability "Kabook" **(a form of Laterite) was selected as bed material for the BGF. From the literature studies and the test results done, it is proven that Kabook is an efficient Phosphorous removing media (Wood & McAtamney, 1996;**Zhang *et al*, 2011; **Liyanage, 2001). The high composition of Fe and Al of Kabook soil (Fe_2O_3-32.58% and Al_2O_3-34.31%) increase the Phosphorous removal process through its adsorption characteristics (**Zhang *et al*, 2011**).**

The purification system contains three BGF cells of each with 20 minutes retention time. The depth of bed material in each cell is 75 mm which is 37.5% of the depth of a cell where the depth of a cell is 200 mm. The tests were performed to check the efficiency of *Kabook* and the results shows that the phosphorous removal efficiency of *kabook* is about 50% for the retention time of 20 minutes and about 80% for the retention time of 1 hour. Variation of phosphate removal efficiency of *kabook* at different time intervals is shown in Fig.8.

The maximum level of phosphate obtained from the laboratory tests was 8.9 mg/l. Since the total retention time of BGF is 1 hour, the expected Phosphorous removal efficiency can be estimated as 80% which is satisfactory to reduce the Phosphorous to meet the permissible level. Zhang *et al*, (2011) have reported higher temperature is suitable for the adsorption reaction of phosphorus onto Laterite. Therefore using Kabook in a tropical country like Sri Lanka it can be expected more positive results.

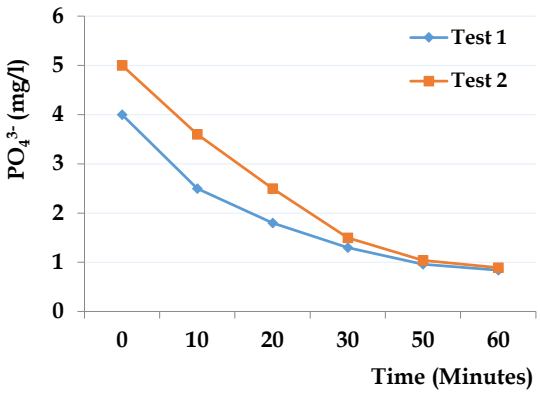

Figure 8Variation of Phosphate removal efficiency of Kabook at different time intervals

5.3The Polishing Pond

The treated wastewater is visualized in the polishing pond before discharging into the Kirulapone Canal. This study not only focuses on wastewater treatment but also provides aesthetically pleasant view to the study area. Therefore, a polishing pond also takes part on later stage of the treatment. The polishing pond is the final segment of the treatment

system which contains the treated water. This pond will contain some bio- indicators to prove the quality of treated wastewater. Flora and Fauna will be introduced in the pond as the indicators which also provide aesthetically pleasant view at the downstream of BGF. The quality of treated wastewater is ensured by the lasting of these bio-indicators.

5.4 Performance of the Treatment System

The treatment system was designed to reduce the pollutants level of the wastewater under the permissible level stipulated by the Central Environmental Authority. The concentration of BOD_5 and phosphate are above the permissible level in dry season. Therefore, special attention was given to these two parameters in the design of treatment system. The maximum BOD_5 value obtained from the test results is 36 mg/l. since the permissible level of $BOD_5$to be discharged is 30 mg/l, the BGF design was done to accomplish the discharge requirements. The maximum phosphate level obtained was 8.9 mg/l and the permissible level was 5 mg/l. According to the design, the phosphate removal of the BGF is 80% which reduces the concentration level far below the permissible level. Moshiri, (1993) obtained removal efficiencies of TSS and COD about 78% and 80-85% respectively by using constructed wetlands. From the similar studies, N removal efficiency in the forms of NH_4^+ -N, NO_3^--N and NO_2^--N is also expected more than 90% (Liyanage *et al*, 2010). Hence the proposed system would be expected high performance similar to those studies.

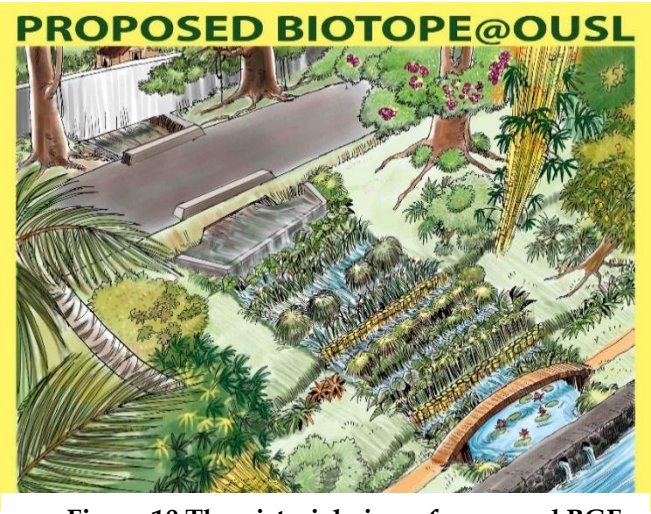

Figure 10 The pictorial view of proposed BGF and Biotope at OUSL premises

Biotope is an area of uniform environmental conditions providing a living place for a specific assemblage of plants and animals. The planting area for biotope is restricted up to 2 m from the embankment of each side of the BGF. The completion of establishment of biotope creates beautiful, pleasant and nature friendly view which will be a useful creation and educational model for the University. A pictorial view of proposed BGF and Biotope at OUSL premises is shown in Fig 10.

5.5 Cost effectiveness

As per the cost estimation, the total cost incurred for the treatment system is Rs 191,000 (U$1470) including the labour cost. With in-house labour, the cost can be reduced to Rs 135,000. Both of these amounts are comparatively very low than the cost incurred for construction of typical wastewater treatment systems.

5.6 Mosquito control

The objective of mosquito control is to suppress the mosquito population below the threshold level required for disease transmission. The following steps will be considered after the implementation of the project. It can be done by introducing of fish which provide effective control as used in FWS constructed wetland in United States (Moshiri, 1993) in the collection pond BGF and polishing pond. Further, removal of unnecessary plants or overgrown plants tightly together which may block the movement of water and by removing any part of plants or any obstacles that block the sunlight on to the water in the treatment system is recommended.

5.7 Stability of the Purification System for flash floods

Although the design for the wastewater purification was done by focusing the dry season, the design for stability of the whole system was done to withstand in wet season when the high flow of water in the stream is occurred. The dam was designed to stable structurally when the high flow in the stream is expected at rainy season. The BGF ditches were designed to withstand without washout in the high flow. Further, the types of plant species selected for BGF and Biotope are capable to exist in high flow of wastewater without any harm.

6CONCLUSIONS AND RECOMMENDATIONS

The proposed treatment system with collection pond, BGF, polishing pond and biotope which provide aesthetically pleasant environment, is an appropriate and economical solution for a polluted stream. This study further reveals that the PO_4^--P removal efficiency of "*Kabook*" **is about 80% and therefore can be used as the geo material for the BGF.** Cantilever retaining wall type of dam design was satisfactory for the soil and geotechnical conditions by increasing the width of footing from 1.5m to 2m in the design. The entire treatment system was designed to withstand during possible flash flood flows during storms.

Further experiments can be carried out with some other locally available geological materials to examine whether those are efficient enough and low cost to employ as bed materials for BGF. It is recommend verifying the applicability of other locally available aquatic plants for suitability according to the condition of the stream such as water level of BGF, depth of root zone, nature of bed material that provides nutrients for root zone. Continuous monitoring is needed to identify the time of replacement of geo material. However, the low-income community to be educated on proper waste disposal methods for preventing further pollutions of water system.

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