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# OUSL Journal

**Volume 11**  
**2016**



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*Editorial*

- 1     *Two-Dimensional Free Space Mesh Generation for Cloud-to-Ground Lightning Simulation using Finite Difference Method*

*N. Kajaluxshy and S. Thirukumaran\**

- 23    *Educational Environment for Undergraduate Medicine and Nursing Programme at Eastern University, Sri Lanka; Students' Perceptions*

*P. Youhasan\* and T. Sathaananthan*

- 37    *Effect of Simulated Temperature and Water Stress on Growth, Physiological and Yield Parameters of Tomato [*Lycopersicon esculentum* var: *Thilina*] Grown with Mulch.*

*P. T. N. Dishani and C. S. De Silva\**

- 53    *Maternity Legislation in Sri Lanka: Are Women Equal, Special or Different?*

*Sunethra M. E. Goonetilleke\**

- 79    *Life with Lost Voice: An Exploration of the Experiences of Patients with Total Laryngectomy.*

*S. S. Rathnayaka, W. K. N. Sajeewani, H. A. S. Piyawardhana, N. K. S. M. Nissanka and B. S. S. De Silva\**

- 93    *Effects of Global Warming Simulated Temperature and Water Stress on Fruit Quality of Tomato (*Lycopersicum esculantum*) Var. *Rajitha*.*

*M. D. M. Gunawardena and C. S. De Silva\**

- 113 *Employability of Graduates of Public and Private Management Education Institutes: A Case Study of Two Institutes in Sri Lanka*

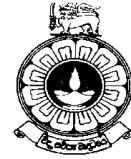
*K. R. Ambepitiya\**

- 135 *Role of Silicon on Enhancing Disease Resistance in Tropical Fruits and Vegetables: A Review*

*Darshani Weerahewa\* and Kosala Somapala*

# OUSL Journal

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## **Editorial - Volume 11, 2016**

This is the eleventh Volume of the OUSL Journal, the Journal of the Open University of Sri Lanka which is published biannually. The articles published in this Volume include research based on physics, floriculture, agriculture, education, social and health sciences.

Lightning is an unexpected electrostatic discharge during an electric storm between electrically charged regions of a cloud (called intra-cloud lightning), or between two clouds (CC lightning), or between a cloud and the ground (CG lightning) or between ground and the cloud (GC lightning). When designing of aircrafts one must consider lightning. Studies of electromagnetic threat due to lightning strikes are important for the safety of an aircraft and its electronic devices. A research paper by Kajaluxshy and Thirukumaran titled “Two-Dimensional Free Space Mesh Generation for Cloud-to-Ground Lightning Simulation using Finite Difference Method” considers the Cloud-to-Ground lightning flash. This paper presents generating a two-dimensional mesh in free space scenario using finite difference method for producing the potential and electric field distribution of the Cloud-to-Ground lightning flash.

Educational environment directly influences the learning process and allows the students to pay more attention on learning. A research study by Youhasan and Sathaananthan assesses the medical and nursing students' perceptions on the educational environment at the Faculty of Health-Care Sciences, Eastern University, Sri Lanka (FHCS, EUSL). The study reveals that, both groups of students perceived the learning environment at FHCS, EUSL was more positive than negative but that a proper supportive system needs to be developed for the students who get stressed or bored with courses.

Temperature stress due to the global warming is a major concern for plant scientists worldwide. Changes in climate may have an impact on agriculture and consequently affect the world's food supply. Dishani and De Silva, in their article titled “Effect of Simulated Temperature and Water Stress on Growth, Physiological and Yield Parameters of Tomato Grown with Mulch” compare the growth, yield

and quality parameters of Tomato (*solanum lycopersicum*) variety Thilina grown with mulch when subjected to temperature and water stress. It was found that, there is a significant effect of mulch on growth parameters of Tomato plants exposed to water and temperature stresses. Higher temperature treatments with saw dust mulch showed significantly higher plant height. The water stress resulted in significant decreases in chlorophyll content and the leaf relative water content. There is a significant effect of water and temperature on yield parameters such as fruit weight, fruit yield *etc.* Thus, tomatoes could be cultivated in green houses at optimum temperature using mulches such as saw dust and coir dust.

A recent Labour Survey indicates female labour force participation as 34.7% and a large portion of the working women are within the child bearing age. Sunethra Goonetilleke in her paper titled “Maternity Legislation in Sri Lanka; Are Women Equal, Special or Different?” critically analyzes and compares the laws governing maternity benefits in Sri Lanka, particularly focusing on the public-private divide, in order to uncover the foundations on which these laws are built. The aspects studied are maternity leave, pay, nursing intervals, job security, health and safety of mother and child, paternity benefits and crèche facilities. It was found that each law dealing with maternity benefits reflects a different legislative intention so that the maternity laws taken as a whole, lack uniformity and thereby unjust to employees of different sectors on no justifiable ground.

Total, partial, supraglottic, and hemi-laryngectomy are the four main types of laryngectomies. Total laryngectomy is a surgical removal of larynx and surrounding structures and it causes the loss of voice. Cancer of the larynx is the most common cause for total laryngectomy. Loss of voice creates emotional and social changes that may result in withdrawal symptoms and depression. The reactions of others persons in society also have a significant impact on these patients’ day-to-day life. Rathnayaka *et al* in their research paper titled “Life with Lost Voice: An Exploration of the Experiences of Patients with Total Laryngectomy” explore the experiences of patients with Laryngectomy among the members of Laryngectomies’ Association of National Hospital of Sri Lanka (NHSL). The findings



revealed that the patients with laryngectomy faced major changes in their lifestyle due to altered airway such as loss of voice, body image concerns, and challenges with eating and communicating.

Climatic changes influence the severity of environmental stress imposed on vegetable crops. Extreme climatic conditions cause negative impact on soil fertility and increase soil erosion. Gunawardena and De Silva in their research paper examine the effects of temperature and water stress on tomato (*Lycopersicum esculantum*) Var. Rajitha. The findings suggest that the temperature stress made the fruits crack and have low moisture content which led to disease attacks and low marketable value for the fruits. Disease outbreak is also heavier in high temperature stress conditions. Therefore, Tomato variety Rajitha could not be a successful open field crop in the dry zone of Sri Lanka, but tomato could be cultivated under green house by providing adequate water and required kind of soil temperature, and management practices.

Kalpana Ambepitiya in her research paper titled “Employability of Graduates of Public and Private Management Education Institutes: A Case Study of Two Institutes in Sri Lanka” investigates the degree of employability of graduates in the public and private sector higher education institutes which offer Management degree programmes. It was found that, academic knowledge, soft, practical and technical skill development are the major factors that prepare an undergraduate for future employment. Salaries, career growth, qualification requirement, relevance to the field of study and family wellbeing are the top most important incentives of private sector employees, but, job security, pension, family wellbeing, travelling distance, time saving and freedom are the main concerns of public sector employees

Weerahewa and Somapala, in a review article, examine the role of silicon on enhancing disease resistance in tropical fruits and vegetables. Silicon is taken up by plants at concentrations similar to the essential nutrients. The beneficial effects of silicon are enhanced insect and disease resistance, reduced mineral toxicity, increased photosynthetic activity, superior nutrient imbalance, and enhanced drought and frost tolerance.

We welcome your suggestions for further improvement of this journal. We look forward to publishing your current research findings in our next volume.

**Professor K. Sarath D. Perera**  
Editor in Chief/OUSL Journal

## **Two-Dimensional Free Space Mesh Generation for Cloud-to-Ground Lightning Simulation using Finite Difference Method**

***N. Kajaluxshy and S. Thirukumaran\****

*Department of Physical Science, Vavuniya Campus, University of Jaffna*

### **Abstract**

The natural lightning environment is a consequence of the interaction of the lightning flash with the aircraft's body. The aircraft can, therefore, be a part of the natural lightning discharge process. Hence, the aircraft becomes exposed by direct effects to the aircraft's body and induced electromagnetic fields to the avionics held within the aircraft due to high power and short time transient. In order to study the expected electric currents and voltages produced over the surface of the aircraft, good knowledge of the waveforms, rates of rise of currents and the voltages produced by direct lightning strikes are required.

The flash of the Cloud-to-Ground lightning is represented as a wave equation which carries the parameters of current and potential of the flash. The objective is to identify the potential flow and electric field distribution along the aircraft conductor represented in the finite difference mesh under the thundercloud of 50MV in 1000m height from the ground. A two-dimensional mesh is generated in free-space using finite difference method for the simulation and the lightning wave is presumed to be traversed in free-space where no gravitational and electromagnetic fields exist and all the boundary conditions are applied. The simulation results are comparatively significant and very useful for studying lightning impact on the aerial vehicles struck by the cloud-to-ground lightning.

**Keywords:** Finite difference method, two-dimensional mesh, cloud-to-ground lightning

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## Introduction

The design of aircraft structure and its protection systems are an important area focused by the manufacturers for flight safety from lightning strike. The metal structures of the aircraft exterior skin normally minimize the lightning effects and prevent physical damage. Modern aircrafts made by the material of carbon fibre or composite materials, being light in weight, can make the airplane fly faster. But the electric shielding effectiveness of carbon fibre is worse than metal materials. The study of electromagnetic threat due to lightning strikes is important for flight safety and restructuring the aircraft design and its electronic devices to mitigate lightning effects.

For the simulation, the lightning wave is presumed to be traversed in free-space where no gravitational and electromagnetic fields exist and all the boundary conditions are applied. To solve partial differential equation, a number of boundary conditions must be imposed. Numerical techniques are necessary for implementing boundary conditions practically.

This paper presents how a two-dimensional mesh is generated using Finite Difference Method for producing the potential distribution in the free-space due to the Cloud-to-Ground lightning flash. Finite difference method (FDM) is an important technique in the field of computations. It is a simple technique for real-time physical processes and developed for solving the wave equation (Thirukumran *et al.*, 2013; Hoole & Hoole, 2011; Hoole, 1993).

The electric field can be determined by finding the maximum rate and direction of spatial change of potential field. The magnitude of the electric field is largest when the derivatives of the potential are maximum. Electric fields can be computed using various methods with different precision. Electric potential  $V$  over any region depends on the  $(x$  and  $y)$  coordinates and its derivatives.

The objective is to find the potential flow at each grid point and represent it graphically. Another objective is to find the potential distribution of a one-dimensional vertical conductor under lightning scenario and to find the electric field distribution around the one-

dimensional vertical conductor in the free-space under the lightning thundercloud.

## **Literature Review**

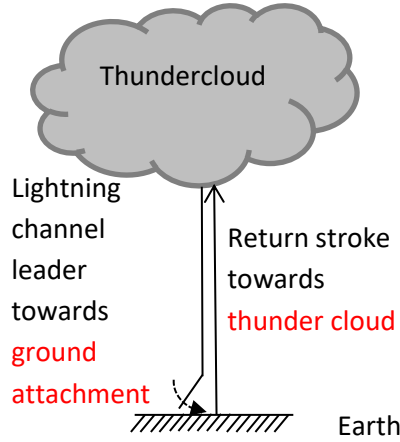
### **Lightning Phenomena**

Lightning is an unexpected electrostatic discharge during an electric storm between electrically charged regions of a cloud (called intra-cloud lightning), between that cloud and another cloud (CC lightning), or between a cloud and the ground (CG lightning) or between ground and the cloud (GC lightning). Lightning is always accompanied by the sound of thunder. Distant lightning may be seen by human eye but may be too far away for the thunder to be heard (Uman, 1984). Many factors affect the frequency, distribution, strength and physical properties of a typical lightning flash in a particular region of the world. These factors include ground elevation, latitude, prevailing wind currents, relative humidity, proximity to warm and cold bodies of water, etc. Lightning can damage or destroy them.

This paper only considers the Cloud-to-ground lightning flash because Cloud-to-Ground lightning is the most studied and best understood of the four types, even though intra-cloud, ground-to-cloud and cloud-to-cloud are more common types of lightning (Hoole *et al.*, 2014; Uman, 1984).

### **Cloud-to-Ground Lightning**

Cloud-to-ground lightning is a lightning discharge between a thundercloud and the ground. Since the base of a thunderstorm is usually negatively charged, negative electric charges in the cloud base (thunderstorm) travel from cloud level to ground. Cloud to Ground (CG) lightning flash primarily originates in the thundercloud and terminates on a physical object that is called as Earth surface. The Cloud-to-Ground flash emanates at the bottom part of the thundercloud and travels to ground. When it connects with the ground, a return stroke wave is produced and this wave travels from ground to cloud as illustrated in Figure 1 (Thirukumran *et al.*, 2013).



**Figure 1.** Cloud-to-ground flash from thunder cloud base to ground level

### **Mesh Generation**

Cloud to Ground vertical lightning scenario is simulated by generating a two-dimensional mesh in free-space using finite difference method. The two-dimensional mesh is formulated using equal number of rows and columns. A structured mesh in two dimensions is most often simply a square grid deformed by some coordinate transformation (Hoole & Hoole, 2011; Hoole & Hoole, 1993). Each node of the mesh, except at the boundaries, has an isomorphic local neighbourhood. Structured meshes offer certain advantages over unstructured. They are simpler and also more convenient for use in the simpler finite difference methods (Causon & Mingham, 2010).

### **Finite Difference Method**

Finite difference method has been applied in an enormous number of numerical computations for a variety of problems in time domain. Finite difference method is developed to solve the wave equation (Causon & Mingham, 2010).

## Lightning Potential Wave Equation

The wave equation for potential  $V$  traveling in free space is given by,

$$\frac{\partial^2 V(z,t)}{\partial z^2} - RC \frac{\partial V(z,t)}{\partial t} - LC \frac{\partial^2 V(z,t)}{\partial t^2} = 0 \quad (1)$$

where  $V$  is the potential while  $R$ ,  $L$  and  $C$  are the resistance per unit length in Ohms, inductance per unit length in Henry and capacitance per unit length in Farad, respectively (Thirukumran *et al.*, 2013; Hoole, 1993].

## Lightning Effects on the Aircraft

The standard lightning environment is comprised of individual current and voltage waveforms, which represent the important characteristics of the natural lightning flashes. The metal aircraft or the conductive parts of the aircraft becomes part of the lightning current (Figure 2). If a conductor carries excess charge, the excess is distributed over the surface of the conductor like aircraft.

Lightning strikes cause direct and indirect damages to aircraft during take-off or landing under thundercloud. Direct effects are physical damage which usually include high voltage and current related damage to metallic or composite structures. Indirect effects are malfunctions, either temporary or permanent, that affect avionics and electrical systems (Gabrielson, 1982). The aircraft designers use analysis, laboratory measurement, and full-scale simulation to develop and demonstrate the immunity of the final design to the effects of the anticipated environment.



**Figure 2.** Lightning flash incident, Heathrow Airport, May 2011  
(Neville, 2011).

There are four important factors which standardize the lightning waveforms significantly used to test the aircraft (Dunbar, 1983; RTCA/DO-160D, 2002):

1. initial stroke with peak amplitude of about 200 kA with action integral of  $2 \times 10^6 \text{ A}^2\text{-seconds}$  in 500  $\mu\text{s}$ ,
2. intermediate average current amplitude of about 2 kA with maximum charge transfer of about 10 C,
3. Continuing current of about 200 A to 800 A with large charge transfer of about 200 C, and
4. restrike peak current on the aircraft body of about 100 kA with action integral of about  $25 \times 10^4 \text{ A}^2\text{-s}$  in 500  $\mu\text{s}$ .

Accordingly, the metallic parts of the aircrafts carry lightning induced current and produce an electric field which could damage the aircraft surface and navigation system of the aircraft adversely.

## **Electric Field**

A fundamental equation for the electric field is Laplace's equation or Poisson's equation, perhaps the simplest among many partial differential equations that express physical phenomena among various numerical calculation methods. The Finite Difference Method is very unique as it is applied exclusively to electric field calculations. This paper is based on the Finite Difference Method.



The Finite Difference Method is not capable of calculating electric field directly at different points on the proposed region. When the potentials of the nodes are obtained, a numerical derivative evaluation technique is used to calculate the electric field intensity (Faiz & Ojaghi, 2002). Relationship between Potential and Electric field is represented by an equation. Here, a gradient operator is used to find the electric field.

The equation is as below:

$$\mathbf{E} = -\nabla V \quad (2)$$

where, the negative sign indicates that the field is pointing in the direction of decreasing potential, Electric field is  $\mathbf{E}$  and Potential is  $V$ .

$$\nabla V = -\int \vec{E} \cdot \vec{dr} \quad (3)$$

In Cartesian coordinates,

$$\mathbf{E} = E_x \hat{i} + E_y \hat{j} \quad (4)$$

$$d\mathbf{r} = dx \hat{i} + dy \hat{j} \quad (5)$$

$$dV = (E_x \hat{i} + E_y \hat{j}) \cdot (dx \hat{i} + dy \hat{j}) = E_x dx + E_y dy \quad (6)$$

which implies,

$$E_x = -\frac{\partial V}{\partial x} \quad , \quad (7)$$

$$E_y = -\frac{\partial V}{\partial y} \quad (8)$$

By introducing a differential quantity called the gradient operator,

$$\nabla \equiv \frac{\partial}{\partial x} \hat{i} + \frac{\partial}{\partial y} \hat{j} \quad (9)$$

The Electric field can be written as,

$$\vec{E} = E_x \hat{i} + E_y \hat{j} = -\left(\frac{\partial V}{\partial x} \hat{i} + \frac{\partial V}{\partial y} \hat{j}\right) = -\left(\frac{\partial}{\partial x} \hat{i} + \frac{\partial}{\partial y} \hat{j}\right) V = -\nabla V \quad (10)$$

Notice that  $\nabla$  operates on a scalar quantity (electric potential) and results in a vector quantity (electric field). Mathematically, we can think of  $\vec{E}$  as the negative of the gradient of the electric potential  $V$ . Physically, the negative sign implies that if  $V$  increases as a positive charge moves along some direction, there is a component of  $\vec{E}$  in the opposite direction.

Let, two-dimensional problem in which the potential does not vary with the  $z$  coordinate. The unknown values of the potential at five adjacent points are indicated as  $V_0, V_1, V_2, V_3$  and  $V_4$  (Figure 3). If the region is charge-free and contains a homogeneous dielectric, then  $\vec{\nabla} \cdot \vec{E} = 0$ , from which we have, in two-dimensions

$$\frac{\partial E_x}{\partial x} + \frac{\partial E_y}{\partial y} = 0 \quad (11)$$

But the gradient operation gives

$$E_x = -\frac{\partial V}{\partial x} \quad , \quad (12)$$

$$E_y = -\frac{\partial V}{\partial y} \quad (13)$$

from which we obtain

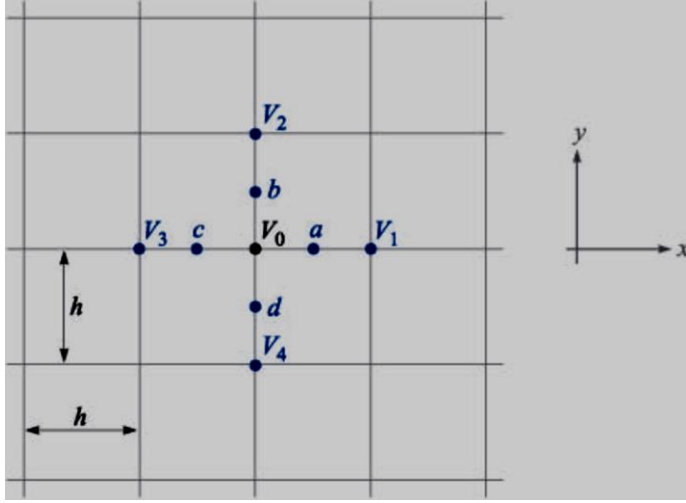
$$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} = 0 \quad (14)$$

This is simply given by the Poisson's equation  $\nabla^2 V = 0$ .

Approximate values for these partial derivatives may be obtained in terms of the assumed potentials, or

$$\frac{\partial V}{\partial x} \Big|_a = (V_1 - V_0) / h \quad (15)$$

$$\frac{\partial V}{\partial x} \Big|_c = (V_0 - V_3) / h \quad (16)$$



**Figure 3.** Squares of length  $h$  on a side, the potential  $V_0$  is approximately equal to the average of the potentials at the four neighbouring nodes.

$$\frac{\partial^2 V}{\partial x^2} \Big|_0 = \frac{\frac{\partial V}{\partial x} \Big|_a - \frac{\partial V}{\partial x} \Big|_c}{h^2} = (V_1 - V_0 - V_0 + V_3) / h^2 \quad (17)$$

$$\frac{\partial^2 V}{\partial y^2} \Big|_0 = \frac{\frac{\partial V}{\partial y} \Big|_b - \frac{\partial V}{\partial y} \Big|_d}{h^2} = (V_2 - V_0 - V_0 + V_4) / h^2 \quad (18)$$

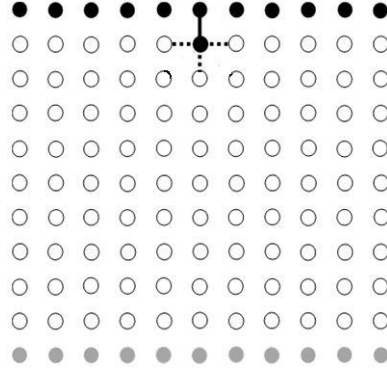
$$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} = (V_1 + V_2 + V_3 + V_4 - 4 * V_0) / h^2 = 0 \quad (19)$$

$$V_0 = (V_1 + V_2 + V_3 + V_4) / 4 \quad (20)$$

The expression becomes exact as  $h$  approaches zero. It is intuitively correct, telling us that the potential is the average of the potential at the four neighbouring points. The iterative method is merely used to determine the potential at the corner of every square subdivision in turn, and then the process is repeated over the entire region as many times as is necessary until the values no longer change (Hayt & Buck, 2014).

## Mesh Generation for Lightning Simulation

### Mesh Generation



**Figure 4.** Initial Cloud-to-ground flash distribution in the mesh

Figure 4 shows a sample square mesh. It can be divided into equal size of rows and columns. It produces lightning discharge patterns in two-dimension. Cloud base and ground level in the mesh are indicated by black and Grey circles respectively. Other grid nodes are indicated by white circles (Perera & Sonnadara, 2012). All the grid points in the two-dimensional mesh in the height from ground level to cloud level will be processed to identify the potential flow of the Cloud-to-Ground lightning flash. The lightning voltage is distributed at each grid point in the free-space. All grid point voltage depends on its four neighbouring node voltage.

Each node point has an electric potential value  $V$  associated with it. Initially the potential of the node points in the upper boundary (cloud base) of the mesh are fixed to 50 MV, while node points in the lower boundary (ground level) are fixed to 0V.

### Initial Environment Potential Distribution

The top row (first row) of the mesh maintains the cloud voltage (50 MV) and bottom row (last row) of the mesh maintains the ground voltage (0V). Except the cloud and ground level grid points, voltage (white circle nodes) is calculated based on the potential difference

between the cloud voltage and ground voltage and the number of rows.

$$D = NC \text{ or number of grid points in the vertical line} - 1 \quad (21)$$

$$C = CV / D \quad (22)$$

$$CRV = PRV - C \quad (23)$$

where,

D = Distance

NC = Number of columns

C = Change or voltage difference

CV = Cloud voltage

CRV = Current row voltage

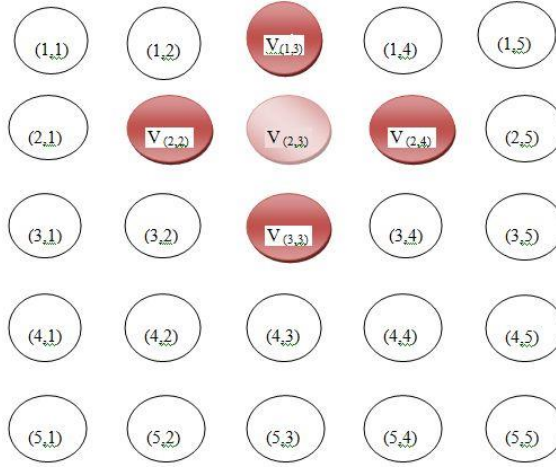
PRV = Previous row voltage

Here, the change means voltage difference between each horizontal line.

We can find voltage of other charge free nodes in the mesh initially using the equation (23).

### **Potential Distribution using Finite Difference Method**

Finite difference method can be used to calculate the potential at the nodes. The accuracy of the numerical results depends on the size of the computational mesh. When we start to find the potential at each node of the mesh using finite difference method we find the potential from top to bottom row wise and left to right in column wise. We start at position (2, 2) go along the whole row, repeat for the next row *etc.*, and eventually end at position (N-1, N-1). Here,  $\Delta x = \Delta y$ .



**Figure 5.** (5×5) matrix (or mesh) potential distribution calculated by finite difference method

This is the general form of finding the potential distribution at each node using finite difference method.

$$V_{i,j} = (V_{i-1,j} + V_{i,j-1} + V_{i,j+1} + V_{i+1,j}) / 4 \quad (24)$$

For example, in Figure 5, the potential at node (2,3) is calculated by:

$$V_{2,3} = (V_{1,3} + V_{2,2} + V_{2,4} + V_{3,3}) / 4 \quad (25)$$

The last interior node in the mesh is (N-1), (N-1), N = n

If we find the potential at node (n-1, n-1) is:

$$V_{n-1, n-1} = (V_{n-2, n-1} + V_{n-1, n-2} + V_{n-1, n} + V_{n, n-1}) / 4 \quad (26)$$

The centre node potential in the mesh is:

$$V_C = (V_T + V_B + V_L + V_R) / 4 \quad (27)$$

where,

$V_C$  = Voltage of the Centre node

$V_T$  = Voltage of the Top node

$V_B$  = Voltage of the Bottom node

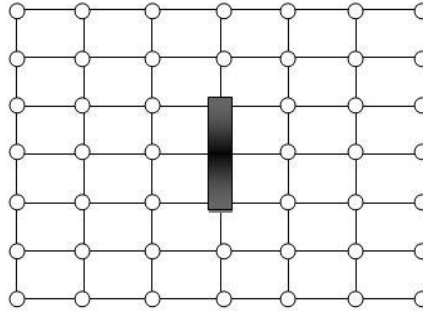
$V_L$  = Voltage of the Left node

$V_R$  = Voltage of the Right node

In this way we can find voltage of all nodes in the mesh using Finite difference method.

### Potential Distribution of a 1-D Vertical Conductor

This paper presents another objective to find the potential distribution and the electric field distribution along the one-dimensional vertical conductor (Figure 6) and other grid points in the mesh using Finite difference method.



**Figure 6.** Mesh contains equal number of rows and columns, after we include one vertical conductor in the middle of the mesh.

Now all the grid points in the mesh contain the potential distribution. The grid points along the one-dimensional conductor also contain the potential value, then find average of those values and assigned this average voltage into all the conductor points to maintain equal conductivity. This average voltage is the initial potential along the conductor points.

All the conductor points have the same initial potential value and then we start to iterate using Finite difference method. It is useful for finding the voltage along the conductor and other grid points in the mesh. Iteration started from top to bottom in the row wise and

left to right in the column wise. If we find the first position of the conductor voltage and assigned this voltage into all other conductor points. Then move to the next node in the mesh. Every time we find the conductor point voltage in the mesh and this voltage is assigned along the conductor points. Last point on the conductor voltage is the final voltage along the conductor points.

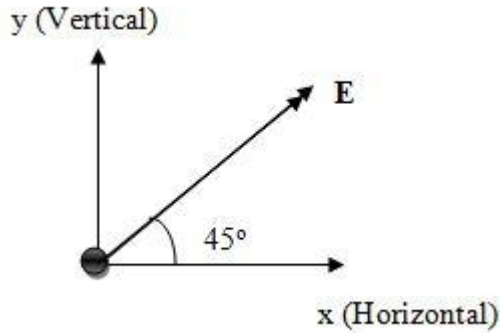
### Electric Field Distribution around the Conductor

We find the Vertical field in the y-direction (vertical). This value depends on potential of the row nodes in the mesh.

$$\text{Vertical field (V)} = (V_{y1} - V_{y2}) / dy \quad (28)$$

Similarly, we can find the Horizontal field in the x-direction (horizontal). This value depends on potential of the column nodes in the mesh.

$$\text{Horizontal field (H)} = (V_{x2} - V_{x1}) / dx \quad (29)$$



**Figure 7.** Electric field in the xy-direction and Total electric field is **E**.

The first component of the equation (11) is in the x-direction. The second component of it is in the y-direction. If we contain the potential of both x and y-direction, then we can find the electric field



around the conductor. Here, equal number of rows and columns are involved so, the degree is 45° (Figure 7).

$$(\text{Electrical field})^2 = (\text{Vertical field})^2 + (\text{Horizontal field})^2 \quad (30)$$

$$E^2 = V^2 + H^2 \quad (31)$$

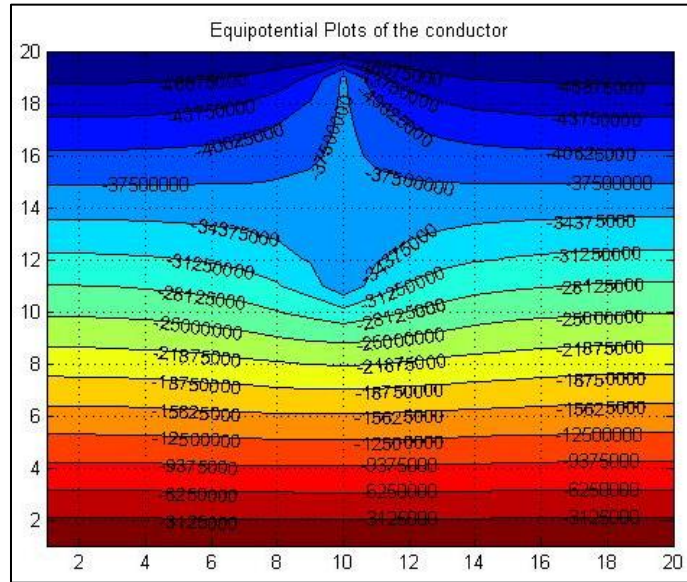
$$E = \sqrt{V^2 + H^2} \quad (32)$$

V and H could be calculated using the equations (28) and (29) respectively. If we know the values of V and H then we can find the value of E.

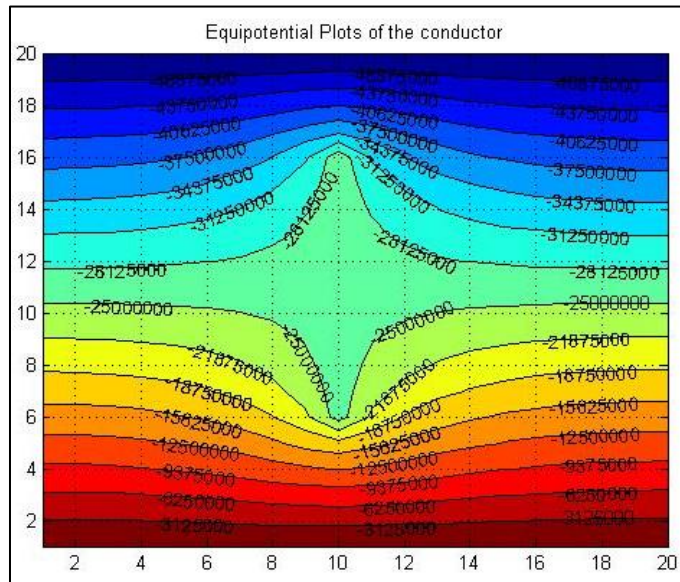
## **Results**

This paper provides a practical overview of numerical solutions of the Cloud-to-Ground lightning wave equation using finite difference method. For the simulation, the inputs are cloud voltage of -50MV and ground voltage of 0V. A negative value is used for cloud voltage since negative charges are accumulated at the bottom of the cloud region from where the lightning leader propagates towards ground. Furthermore, the stability and the accuracy of finite difference time domain method (FDTD) are ensured by numerical computation to identify the lightning characteristics (Hoole & Hoole, 2011).

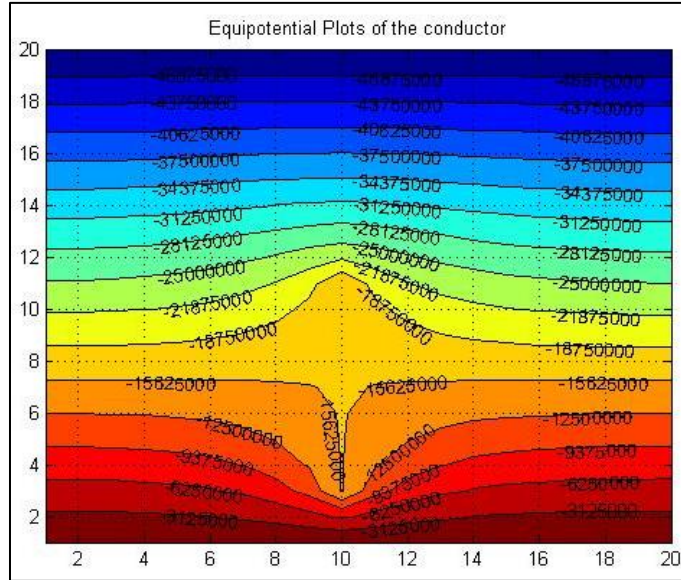
Figure 8 shows, the potential distribution along the 1-D vertical conductor located below the thundercloud in three different heights above the ground. In the figures, high voltage appeared closer to the cloud level in blue and low potential values are indicated closer to the ground level in red. The potential distribution along the vertical conductor closer to the cloud level (Figure 8(a)), middle level (Figure 8(b)) and closer to the ground level (Figure 8(c)) are shown. The potential of the conductor remains constant in each of the cases.



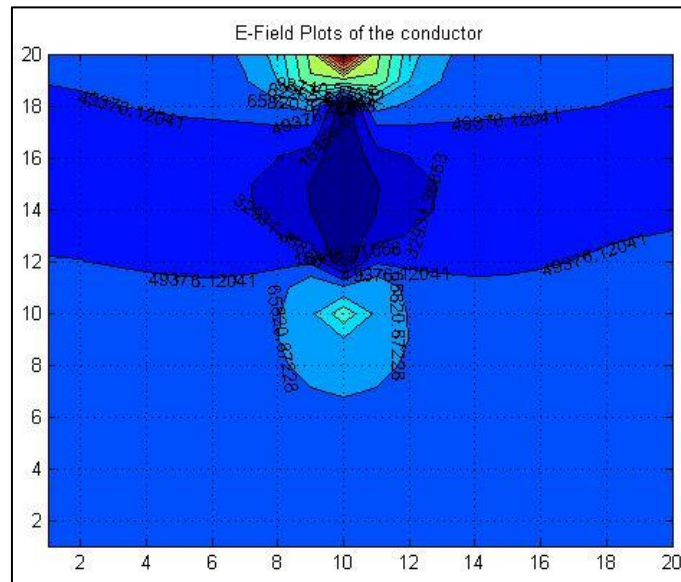
**Figure 8(a).** Potential distribution of a 1-D vertical conductor closer to the cloud level



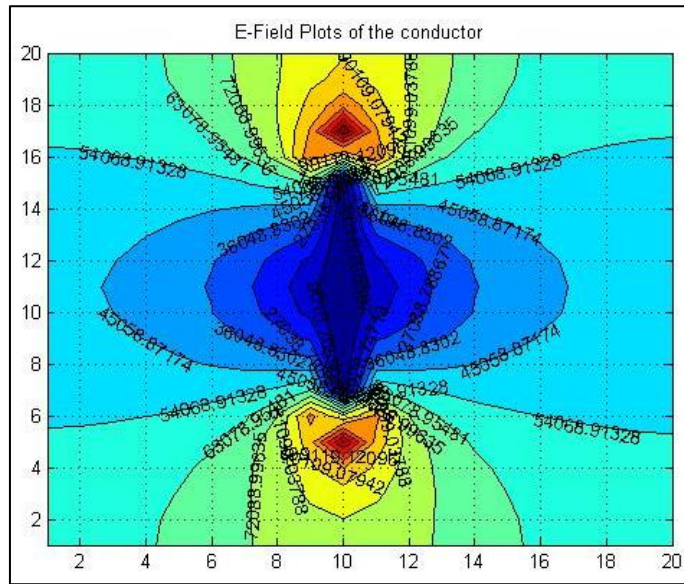
**Figure 8(b).** Potential distribution of a 1-D vertical conductor at middle



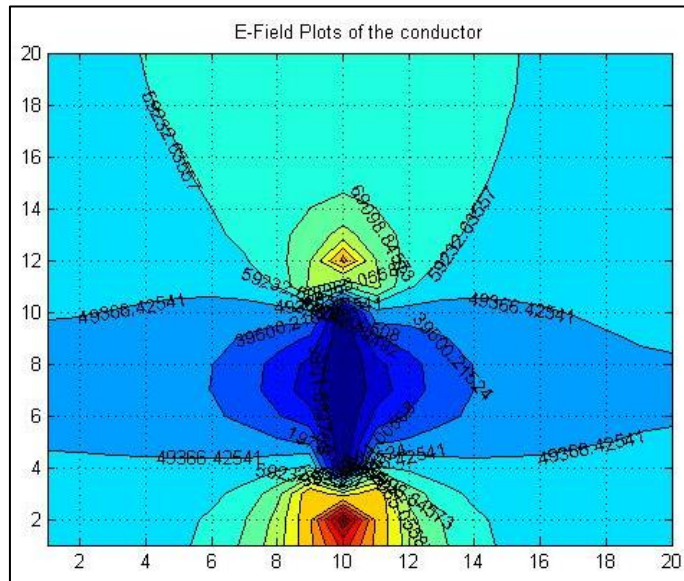
**Figure 8(c).** Potential distribution of a 1-D vertical conductor closer to the ground level



**Figure 9(a).** Electric field distribution around the 1-D vertical conductor closer to the cloud level



**Figure 9(b).** Electric field distribution around the 1-D vertical conductor at middle



**Figure 9(c).** Electric field distribution around the 1-D vertical conductor closer to the ground level

Figure 9 shows the initial simulation results for the electric field distribution around the one-dimensional conductor located in three different heights: closer to the cloud level (Figure 9(a)), middle level (Figure 9(b)) and closer to the ground level (Figure 9(c)) are shown under the thundercloud and above the ground. The simulation results show the electric field distribution at the end points of the conductor is significant and much higher than the electric field distribution of other points around the conductor because of the sharp edges. High electric fields are indicated by red at the endpoints. The electric field on the interior points along the conductor is zero in all three cases since the vertical potential difference is zero on the conductor. The initial simulation shows that the magnitude of radiated electric fields interacts with the aircraft resulting in adversely on the aircraft navigation systems which may cause damage to its structures.

The Figure 8 and 9 give initial simulation results for the potential and electric field distribution of a single vertical conductor under the lightning scenario. The potential and electric field distribution are to be identified for different shapes of the conductor to measure its effects. The above study would help to model the aircraft and identify the lightning effects on the aircraft surface and around it. Moreover, it is assumed that the fuselage of an aircraft being a good conductor and the effects of material properties are left for future studies.

## **Conclusion**

The aircraft-lightning interaction under the thundercloud and above the ground is considered. This paper presents generating a two-dimensional mesh in free space scenario using finite difference method for producing the potential and electric field distribution of the Cloud-to-Ground lightning flash. In the simulation, the lightning voltage was distributed numerically at each grid point and graphically represented. A significant increase of induced electric field was observed in the simulation due to the lightning stroke to aircraft conductor. The potential and electric field distribution are developed along and around the one dimensional conductor and

other grid points in the mesh in between the thundercloud and the ground.

In this initial simulation, the voltage surges and the electric field distributions are computed and it is reported that a higher rate of rise of electric field was observed due to cloud to ground lightning flash. These measures obtained would be very useful for developing lightning impact on the aerial vehicles struck by the cloud-to-ground lightning. The work presented in this paper would also be useful for further extension of modelling the conductor like aircraft with the effects of material properties.

Furthermore, according to the evidences which show that the aircraft initiates lightning during take-off under thundercloud, the presented work could be extended to study situations where the aircraft-lightning interaction occurs in different heights while flying between subsequent lightning strikes to identify the effects on the surface of the aircraft and avionics within the aircraft.

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## **Educational Environment for Undergraduate Medicine and Nursing Programme at Eastern University, Sri Lanka; Students' Perceptions**

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### **Abstract**

Educational environment directly influences the learning process and allows the students to pay more attention on learning. This study was aimed to assess the students' perceptions on the educational environment at Faculty of Health-Care Sciences, Eastern University, Sri Lanka (FHCS, EUSL). This survey was performed on academic year 2014/2015 with the use of Dundee Ready Education Environment Measure (DREEM) questionnaire. 156 (114 Medical & 42 Nursing) students participated. The scores of perception statements were converted into continuous variables and summarized as means. T-test was used to compare students' perception between programme of study. The results revealed that as per the DREEM analysis, the learning was perceived more positive (27/48), the teaching was moving in the right direction (24/44) and the academic self-perceptions was felt more on the positive side (19/32). However, there were many issues in atmosphere (24/48) and the social self-perception was also not too bad (16/28). The overall DREEM mean score was 111 out of 200, which indicates that there was a more positive educational environment than negative in FHCS, EUSL. Furthermore, students identified problems with regard to the supportive system when they got stressed and relax learning atmosphere during lecture & tutorial. Hence, the faculty needs to identify strategies to improve weaker areas which were identified in the study. Subsequent studies should

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be conducted in future to assess the results of the corrective strategies and further exploration.

**Keywords:** Education environment, faculty of health-care sciences eastern university, medicine, nursing, dreem questionnaire.

## Introduction

Education environment is one of most important factors determining the learning process (Roff & McAleer, 2001). It affects the learner motivation and engagement on learning (Hutchinson, 2003). Effective educational environment positively correlates with the optimal outcome of an educational institution (Abdulrahman, 2013).

Education environment is an indispensable part of the curriculum, affecting the interaction between student, methods, assessment, and educational outcomes (Palmgren & Chandratilake, 2011). Therefore, assessing the educational environment is important to identify the problematic areas in a particular institution. It would assist the curriculum planner to do the necessary adjustment to achieve the optimal educational outcome. In this regards, internationally and nationally, several studies were carried out to measure the educational environment with the use of Dundee Ready Education Environment Measure (DREEM). DREEM is a globally accepted tool to measure the education environment in medical and allied health institutions (Khan *et al.*, 2011).

At present, there are ten state universities conducting health professional degree programmes in Sri Lanka, namely; University of Colombo, University of Sri Jayewardenepura, University of Peradeniya, University of Kelaniya, University of Jaffna, University of Ruhuna, Eastern University, Rajarata University, Open University, Sri Lanka and Sir John Kotalawala Defense University. Among these, several universities have been assessed their education environment.

Faculty of Health-Care Sciences (FHCS) is the youngest faculty of the Eastern University, Sri Lanka (EUSL). It was established on 2005. There are two programme being conducted by the faculty, namely; Bachelor of Medicine, Bachelor of Surgery (MBBS) and Bachelor of Science in Nursing [BSc.(N)]. FHCS is one of the medical faculties in Sri Lanka following the spiral model, integrated, modular curriculum. Curriculum and Educational environment influences the effectiveness of education. The curriculum and its delivery are

periodically monitored by the faculty but education environment is not regularly assessed. Thus, this study was aimed to assess the students' perception of the educational environment at the FHCS, EUSL. The findings of this study could be used as a basis to support curriculum planners at FHCS to improve the medicine and nursing programme and also it will serve as a longitudinal first review evidence to support future study at FHCS.

## **Review of Literature**

### **Education Environment**

The educational environment is defined as everything that happens within the classroom, department, faculty or university which is crucial in determining the success of undergraduate medical education (Genn, 2001; Roff & McAleer, 2001). It is synonymous with climate, atmosphere or ambiance, which is multifaceted and can be described as an educational institution's personality, spirit, and culture (Palmgren & Chandratilake, 2011).

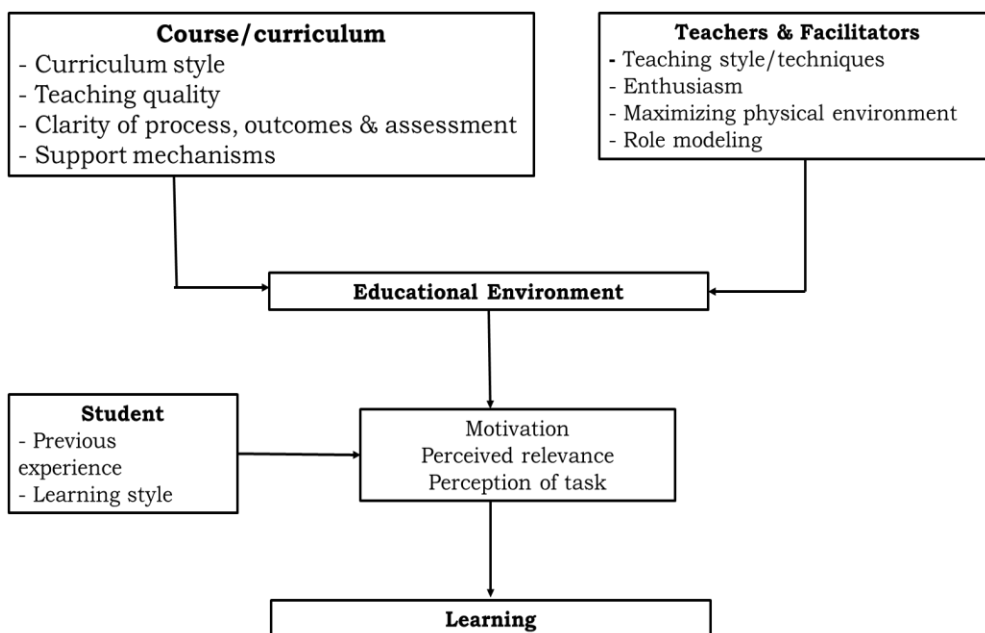
### **Influence of Educational Environment on Learning**

Engaging the students on learning is the ultimate goal of education. There are many factors which influence on learning (Figure 1). Learning mainly depends on learners' motivation and their perception of relevance. These, in turn, can be affected by the learners' previous experiences, preferred learning styles, context and environment in which the learning is taking place (Hutchinson, 2003). Education environment is one of the most important factors to determine the effective curriculum. Educational outcome may vary among the institutions where the curriculum remains the same because of the educational environment changes from one institution to another (Khan *et al.*, 2011).

### **Maximizing the Educational Environment**

The curriculum designers of the programme should consider the suitability of the learning environment to potentiating learning. The teaching methods should build on learners' experience, creating a collaborative environment. In longer courses, student support systems and informal activities that build collective identity must be considered. Room temperature, comfort of seating, background noise, and visual distractions are the physical factors that need to be considered in designing the classroom. Clinical setting is an important environment for health-care students. Arranging adequate space, and assigning students' roles in clinical setting are crucial

tasks of programme planners. The dual role of teacher and clinician can be complicated. The students will be closely observing the clinician and picking up hidden messages about clinical practice. They need to feel that there is no danger that they will unnecessarily distress or harm patients or their families. They also need to feel safe from humiliation (Hutchinson, 2003).



**Figure 1.** Factors influence on learning(Hutchinson, 2003).

## Measuring the Education Environment

There are several instruments available to measure the medical education environment. Roff *et al.* (1997) developed the Dundee Ready Education Environment Measure (DREEM) with a panel of nearly 100 medical educators and 1000 students to measure and 'diagnose' undergraduate educational climates in the health professions. It is a generic, multidimensional, multicultural instrument validated and used in developed and developing countries with considerable success in profiling the perceived weaknesses and strengths of medical and allied institutions (Khan *et al.*, 2011). It allows quality assurance comparisons to be made between courses as well as within components of a course (Roff &

McAleer, 2001; Roff, 2005).

DREEM inventory consists of 50 questions, each scoring 4, thus giving a cumulative maximum individual DREEM score of 200. The scores are, 4-strongly agree, 3-agree, 2-unsure, 1-disagree and 0-strongly disagree. Items with a mean score of 3 and above are considered positive and items with a mean score of 2 and below are considered as problem areas and were identified in the study population. Items with a mean score between 2 and 3 are considered as aspects of the educational environment that require enhancement. The following is an approximate guide to interpreting the overall score: 0-50 Very Poor, 51-100 Plenty of Problems and 101-150 More Positive than Negative, 151-200 Excellent (Roff *et al.*, 1997).

The inventory consists of five subscales namely perceptions of learning, perceptions of teaching, self-academic perceptions, perceptions of atmosphere and social self-perceptions. The scores for each subscale were interpreted on a four-tiered scale as mentioned in below.

Students' Perception of Learning: 0-12 Very Poor; 13-24 Teaching is viewed negatively; 25-36 A more positive perception; 37-48 Teaching highly thought of. Students' Perception of Teachers: 0-11 Abysmal; 12-22 In need of some retraining; 23-33 Moving in the right direction; 33-44 Model course organizers. Students' Academic Self-Perception: 0- 8 Feelings of total failure; 9-16 Many negative aspects; 17-24 Feeling more on the positive side; 25-32 Confident. Students' Perceptions of Atmosphere: 0-12 A terrible environment; 13-24 There are many issues which need changing; 25-36 A more positive; 37-48 A good feeling overall. Students' Social Self Perceptions: 0-7 Miserable; 8-14 Not a nice place; 15-21 Not too bad; 22-28 Very good socially (Roff *et al.*, 1997).

### **Medical Educational Environment Measured by DREEM**

A Pakistan study revealed that DREEM score of the private medical institution (X=137) was significantly higher than in the public sector (X= 115) (Khan *et al.*, 2011).

First year students (119/200) were satisfied with the learning environment compared to the clinical batch student (114/200) at Melaka Manipal Medical College, India (Abraham *et al.*, 2008).

Educational environment in the Qassim University Medical College, Saudi Arabia was more positive than negative (112/200). There were

no significant differences of perceptions between genders and phases of the programme (Abdulrahman, 2013).

339 students from pre, para & clinical phases in Faculty of Medical Sciences, University of Sri Jayewardenepura (FMS/USJ) participated in a study to measure the education environment. Overall DREEM score was 108. Students' perception on teachers, Self-academic and self-social perceptions were significantly different among the phases (Jiffry *et al.*, 2005).

A majority (65.6%) of students in University of Colombo, Faculty of Medicine (UCFM) stated that the education environment in the UCFM was 'more positive than negative' (107/200) to the DREEM inventory (Lokuhetty *et al.*, 2010).

Nursing students perceived relative satisfaction with the educational environment in University of Ruhuna and they also identified problematic areas that need improvement (Manjula & Chandana, 2012).

## **Methodology**

It was a descriptive cross-sectional study conducted in FHCS, EUSL during the academic year of 2014/2015. Final year and year prior to final year medical and nursing students were selected as the study population. Non-probability sampling method was used to collect convenience samples from study population.

Self-administered DREEM questionnaire was used to collect perception data from students. All questionnaires were coded and entered into an electronic database. The scores for the statements relating to negative attributes were computed in the reverse order. Data analysis was carried out using SPSS version 22. Descriptive statistics were computed to present distribution of study participants by student's programme of study. T-test was used to compare students' perception between the programme of study. Ethical clearance was obtained from the ethics review committee of FHCS, EUSL.

## Findings

There were 156 students of FHCS, EUSL who participated in this study. They consisted of 114 and 42 students in MBBS and BSc in nursing programme respectively. There were 95 females in the study group. The total mean DREEM score was 111 out of 200, which indicates that there was “more positive educational environment than negative” in FHCS, EUSL. (Table 1).

Most of the students had a positive perception about learning at FHCS, EUSL (Table 1). However, enhancement requires to determine student centered learning. Nursing students identified a problem; they were not clear about the learning objectives of the course. Nursing students had high likelihood perception in teaching which helped to develop their competencies and teaching time put for good use (Table 2).

The students' perception on teachers' was in right direction (Table 1). Students perceived problems among teachers' role on affective changes during teaching session. The overall students' perception on the teachers' effective communication was significantly different among course (Table 2).

**Table 1.** MBBS & BSc(N) students' perception of education environment in FHCS, EUSL and its interpretation

Areas of students' perception	DREEM Mean ( $\bar{X}$ )			Interpretation
	MBBS	BSc.(N)	Overall (S.D)	
01. Students' Perceptions on Learning	27.11	27.50	27.21 (6.78)	More positive perception
02. Students' Perceptions on Teachers	23.80	24.81	24.07 (4.92)	Moving in the right direction
03. Students' academic self-perception	18.80	20.76	19.33* (4.64)	Feeling more on the positive side
04. Students' Perceptions on Atmosphere	23.91	24.98	24.20 (7.42)	There are many issues which need changing
05. Students' Social Self Perceptions	14.69	16.38	15.54* (4.32)	Social life is Not too bad

06. <b>Overall Perception</b>	108.31	114.43	111.37 (5.02)	More Positive environment than Negative
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\* Significant *p*-value, *S.D* - Standard deviation

Students' academic self-perception was more on the positive side (Table 1). Learning strategies, problem solving skills and career relevant learning were significantly different among courses. However, both groups of students had problems in being able to memorize all they need (Table 2). Students' perceived social life in the faculty was not too bad (Table 1). Also they identified problems with the good support system for students who get stressed (Table 2). There were many issues found by students' perception on learning atmosphere (Table 1). The students have perceived problems on relax learning atmosphere during lecture or tutorials, learning atmospheric motivation and course timetable (Table 2).

## Discussion

Education environment at FHCS was assessed by the study after nine years of its establishment. DREEM was used to assess the educational climate. This tool is globally recognizable to assess the educational environment at medical institutions.

This study revealed that overall student perception about education environment at FHCS, EUSL was "More Positive environment than Negative". This finding coincided with the earlier studies which were conducted in different universities in Sri Lanka. Education environment of UCFM was perceived as positive (107/200) by a majority of students (Lokuhetty *et al.*, 2010). Students had positive perception about education environment (107/200) at FMS/USJ (Jiffry *et al.*, 2005). Furthermore, nursing students felt relative satisfaction with the perceived environment (109/200) at University of Ruhuna (Manjula & Chandana, 2012). The above mentioned DREEM scores obtained in Sri Lankan studies were less favorably compared with the total mean scores achieved in University of Dundee (139/200) (Al-Hazimi *et al.*, 2004), Birmingham Medical School (139/200) (Varma, Tiyaqi & Gupta, 2005), Koirala Institute of Health Sciences, Dharan, Nepal (130/200) (Roff *et al.*, 2001).

Nursing students' overall perception (114/200) about education environment at FHCS, EUSL was high compared to the medical students (108/200). Among the 50 items on the DREEM inventory, 37 items had a mean score between 2.00 to 3.00. These items are



aspects of the educational environment that could be enhanced. A

total of 16 items scored below 2.00. These could be identified as problem areas in FHCS educational environment that require further improvements. Furthermore, no item received a mean score of three or more, which indicates that students have not perceived satisfaction with any item. Student gave the highest rating (2.88) to the statement of; “The teachers are knowledgeable”. Meanwhile lowest rating (1.43) went to “The course is well timetabled”.

**Table 2.** Mean score for the DREEM among Students’ perception of education environment at FHCS, EUSL.

Statements of Students' Perceptions	DREEM Mean (X)		
	MBBS	BSc. (N)	Overall
<b>Students' Perceptions about learning</b>			
I am encouraged to participate in teaching sessions	2.54	2.95	<b>2.75</b>
The teaching is often stimulating	2.58	2.55	<b>2.56</b>
The teaching is student centered	2.46	2.71	<b>2.59</b>
The teaching helps to develop my competence	2.44	2.83	<b>2.64*</b>
The teaching is well focused	2.15	2.48	<b>2.31</b>
The teaching helps to develop my confidence	2.29	2.31	<b>2.30</b>
The teaching time is put to good use	2.09	2.29	<b>2.19*</b>
<i>The teaching over emphasizes factual learning</i>	1.74	1.40	<b>1.57</b>
I am clear about the learning objectives of the course	2.23	1.86	<b>2.04*</b>
The teaching encourages me to be an active learner	2.43	2.26	<b>2.35</b>
Long term learning is emphasized over short term learning	2.05	2.14	<b>2.10</b>
<i>The teaching is too teacher centered</i>	2.11	1.71	<b>1.91</b>
<b>Students' Perceptions about Teachers</b>			
The teachers are knowledgeable	2.86	2.90	<b>2.88</b>
The teachers espouse a patient centered approach to consulting	2.28	2.36	<b>2.32</b>
<i>The teachers ridicule their students</i>	1.68	2.02	<b>1.85</b>
<i>The teachers are authoritarian</i>	1.55	1.43	<b>1.49</b>
The teachers appear to have effective communication skills with students	2.33	2.69	<b>2.51*</b>

The teachers are good at providing feedback to students	2.17	2.19	<b>2.18</b>
The teachers provide constructive criticism here	1.75	2.07	<b>1.91</b>
The teachers give clear examples	2.33	2.50	<b>2.42</b>
The teachers get angry in teaching sessions	2.06	1.74	<b>1.90</b>
The teachers are well prepared for their teaching sessions	2.58	2.43	<b>2.50</b>
<i>The students irritate the course teachers</i>	2.19	2.48	<b>2.33</b>
<b>Students' Perceptions about Academic Self-Perception</b>			
Learning strategies which worked for me before continue to work for me now	2.49	2.95	<b>2.72*</b>
I am confident about passing this year	2.69	2.71	<b>2.70</b>
I feel I am being well prepared for my profession	2.47	2.64	<b>2.56</b>
Last year's work has been a good preparation for this year's work	2.29	2.60	<b>2.44</b>
<i>I am able to memorize all I need</i>	1.96	1.64	<b>1.80</b>
I have learned a lot about empathy in my profession	2.39	2.69	<b>2.54</b>
My problem solving skills are being well developed here	2.18	2.67	<b>2.43*</b>
Much of what I have to learn seems relevant to a career in healthcare	2.31	2.86	<b>2.58*</b>
<b>Students' Perceptions about Social Self Perceptions</b>			
There is a good support system for students who get stressed	1.62	1.69	<b>1.66</b>
I am too tired to enjoy this course	2.06	2.36	<b>2.21</b>
I am rarely bored on this course	1.69	2.14	<b>1.92</b>
I have good friends in this course	2.73	2.88	<b>2.80</b>
My social life is good	2.67	2.83	<b>2.75</b>
I seldom feel lonely	1.93	2.10	<b>2.01</b>
My accommodation is pleasant	1.99	2.38	<b>2.19</b>
<b>Students' Perceptions about Atmosphere</b>			
The atmosphere is relaxed during consultation teaching	2.04	2.21	<b>2.12</b>
The course is well timetabled	1.40	1.45	<b>1.43</b>
<i>Cheating is a problem in this course</i>	1.98	2.19	<b>2.09</b>
The atmosphere is relaxed during lectures	1.68	1.83	<b>1.75</b>
There are opportunities for me to develop interpersonal skills	2.20	2.26	<b>2.23</b>

I feel comfortable in teaching sessions socially	2.19	2.29	<b>2.24</b>
The atmosphere is relaxed during seminars/tutorials	1.86	1.83	<b>1.85</b>
I find the experience disappointing	2.25	2.21	<b>2.23</b>
I am able to concentrate well	2.16	2.26	<b>2.21</b>
The enjoyment outweighs the stress of studying medicine	2.00	2.26	<b>2.13</b>
The atmosphere motivates me as a learner	1.94	1.83	<b>1.89</b>
I feel able to ask the questions I want	2.21	2.33	<b>2.27</b>

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*the items in italics were negative questions, \* significant p value*

## Conclusions

The present study revealed that, both groups of students perceived the learning environment at FHCS, EUSL was more positive than negative. Nevertheless, the study also revealed problematic areas of learning atmosphere. It is recommended that a suitable relaxed learning atmosphere at FHCS, EUSL must be established. A proper supportive system should be developed for the students who got stressed or bored on courses. Student centered learning must be determined in the faculty such as Problem Based Learning. Periodical feedback/programme must be initiated to develop students' attitude. Hence, faculty needs to identify the strategies to improve weaker and problematic areas which were identified in the study. Subsequent studies should be conducted in future to assess and/or monitor the results of the implemented strategies.

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## **Effect of Simulated Temperature and Water Stress on Growth, Physiological and Yield Parameters of Tomato [*Lycopersicon esculentum* var: *Thilina*] Grown with Mulch**

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### **Abstract**

Understanding the effect of temperature stress on growth and yield of crops, and also identifying suitable management options to sustain the productivity under different changes in the natural environment are of timely importance. The main aim of this research is to compare the growth, yield and quality parameters of Tomato (*solanum lycopersicum*) variety Thilina grown with mulch when subjected to temperature and water stress if there is global warming. The plants were grown in pots under temperature-controlled poly tunnels. Main plot included two different irrigation applications (no water stress by irrigation to field capacity moisture level and, water stress by irrigating only up to the 50% of the available water capacity). Coir dust and saw dust were used as mulch and sub plots contained 3 different temperature regimes (34°C maximum temperature poly tunnel/32°C maximum temperature polytunnel/Open space-ambient temperature). The treatments were set up in a completely randomized design with 3 replicates. To make sure of the temperature replication, the trials were repeated 3 times. According to the results, there is significant effect of mulch on growth parameters of Tomato plants exposed to water and temperature stresses. Individual water stress showed a highly significant effect on growth, and yield parameters of Tomato. High yield reduction was shown in the high temperature (34°C) and water stressed plants. Mulching of saw dust and coir dust improved the yield even at 34 °C temperature treatment. Therefore, Tomato variety Thilina would not be a successful crop in open field condition due to temperature and water stress if there is global warming, but mulching will help to improve the situation.

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**Keyword:** Climatic change, water stress, temperature stress, mulch

## Introduction

Studies in Sri Lanka based on HadCM3 general circulation model have revealed that the temperature will increase in the coming years. It was also reported that in 2050, the highest temperature increase by 2°C is predicted in Anuradhapura compared to the baseline temperature during the period of 1961-1990 (De Silva *et al.*, 2007). Further, the rainfall during northeast monsoon is predicted to decrease in the dry zone area (De Silva *et al.*, 2007). Therefore, the decrease in rainfall and increase in temperature will increase the evapotranspiration and soil moisture deficits. Accordingly, agricultural activities in the dry zone may be affected by predicted climate change in Sri Lanka (De Silva *et al.*, 2007). A significant change in climate on a global scale will impact agriculture and consequently affect the world's food supply. Temperature stress is becoming the major concern for plant scientists worldwide due to the global warming as a result of climate change. The conservation of soil moisture may help in preventing the loss of water through evaporation from the soil facilitating maximum utilization of moisture by the plants. Mulching is a method by which soil moisture can be conserved (Sandal and Acharya, 1997). Moreover, mulching regulates the soil temperature and improves the soil physical properties.

Agricultural crops are affected by global warming due to the relationship between crop development, growth, yield, with atmospheric CO<sub>2</sub> concentration and climatic conditions. Temperature related extreme indices have increased over most locations in Sri Lanka. Annual average rainfall over Sri Lanka has been decreasing for the last 57 years at a rate of about 7 mm per year (Ranasinghe *et al.*, 2014). The coefficient of variation of rainfall distribution between 1931 and 1960 is greater during the Northeast monsoon and Second inter monsoon period (*Maha Season*) when compared to the period from 1961-1990. Southwest monsoon rainfall has not shown any significant change during these two periods. However, variability has decreased during 1961-1990 compared to 1931-1960 period (Ranasinghe *et al.*, 2014). When temperature exceeds the optimum for biological processes, crops often respond negatively with a steep drop in net growth and yield (Chynthia and Hillel, 1995). 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).

Yield is positively related to the amount of incoming solar radiation intercepted by the plants in a long season crop. Termination of growth of small fruits is sometimes induced by high temperatures and high light conditions. Tomato is one of the major fruit vegetables in the world. In Sri Lanka it is annually cultivated more than 220 ha, producing approximated 3400 metric tons (Ranasinghe *et al.*, 2014). However, the average productivity of Tomato in Sri Lanka (2 metric ton/ha) is much lower than the world average, may be due to the seasonal weather changes which adversely affect the average productivity. Meantime, a shortage in the month of peak rain fall (May and November) and a production glut in the month of harvesting (March to May and September to October) lead to a dichotomy in the distribution of annual Tomato production.

Therefore, this research is focused on the evaluation of the effect of temperature and water stress on growth and yield of Tomato (*solanum lycopersicum*, var: Thilina) grown with the application of a mulch.

## **Methodology**

The experiment was set up in the agricultural field poly tunnels of the Open University at Nawala.

Nursery management was initiated and the Tomato seedlings were transplanted into individual plastic pots (1 plant/ pot according to the Department of Agriculture recommendation for Tomato variety Thilina. The pots were filled with a compost and sandy loam soil mixture at the ratio of 1:1. Two mulching treatments namely coir dust and saw dust (mixture of timber species especially, teak and jak) were used. Un- mulched treatment was considered as control.

Two mulches were added for 5cm thickness until the surface of the compacted soil was within 1.5 cm of the rim. Initial height of the Tomato seedlings was 12 cm. These Tomato plants were grown at 3 different temperature conditions; 34°C and 32°C maximum air temperature in poly tunnels and ambient temperature in open space out side the poly tunnel. Poly tunnels were made with temperature regulation and ventilation fans. When the temperature is set at the poly tunnel for 34°C and if the temperature rose above that set temperature, the ventilation fans automatically start in operation until the temperature is brought down to the set temperature. Open space on the top of the poly tunnel facilitates the free air circulation.



A two factor factorial experiment was carried out in three replicates. Pots are arranged according to the complete randomized design (CRD), resulting in a total of 54 pot-grown plants. Temperature and mulches were taken as factors. Experiment was repeated thrice in order to fulfill the temperature replication instead of having three poly tunnels for each temperature. Physiological, morphological, yield and quality parameters of Tomato were investigated during the growing and reproductive periods. Analysis of variance (ANOVA) was performed using the statistical program Minitab (version 14, Minitab Inc.). Significant differences specified were all at ( $p < 0.05$ ).

## **Growing conditions**

In the management of Tomato plants, cultural practices recommended by the Department of Agriculture for fertilizing, weeding etc. were adopted except water management. A basal dressing was applied at the transplanting, and top dressing was applied at 3rd and 6th week after planting. Chemical controls of diseases were done by application of “C-CRON PROFENOFOS” 6th and 8th week after planting. Irrigation management was done according experimental designing. Every day the soil moisture of the pots was measured and the water was applied to the field capacity level for the no water stress treatments plants. Water stress treatment plants were watered with half the volume of the water applied for the no water stress treatment plants. However, water stress develops during the day due to evaporation and transpiration.

## **Water management**

Field capacity ( $\theta_{fc}$ ) and permanent wilting point ( $\theta_{pw}$ ) were determined using the pressure plate method. Calculated field capacity and permanent wilting point moisture contents were 44% and 13% respectively. Above values were used in computing the percentage depletion of plant available water (PAW) for the water stress treatments. Treatments under water stress of 50% soil moisture deficit level (50% depletion of plant available water from the soil moisture at field capacity), the plants received irrigation only when PAW was depleted by 50% or more, i.e. below,

$$44 - [0.50 \times (44 - 13)] = 28.5 \text{ soil moisture}$$

All the no water stress treatment pots were watered up to field capacity level every day in the morning. However, the water stress develops during the day due to evaporation and transpiration.

## **Climatic data**

All the climatic data such as rainfall, temperature and relative humidity were collected from Meteorological Department, Colombo. Air temperature inside the tunnel, temperature in the soil and mulch were measured using a digital thermometer with an electric sensor.

## **Crop physiological data collection**

### **The leaf relative water content**

The leaf relative water content was determined in the fully expanded top most leaf of the main shoot. The fresh weight of the sample leaves was recorded and the leaves were immersed in distilled water in a Petri dish. After 2 hrs, the leaves were removed, the surface water was blotted-off and the turgid weight was recorded. Samples were then dried in an oven at 70 °C to constant weight. Leaf relative water content was calculated using the following formula.

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

Where: F.W. = Fresh weight; D.W. = Dry weight;

T.W. = Turgid weight.

### **Leaf chlorophyll content**

SPAD-502 chlorophyll meter (Minolta Camera Co., Osaka, Japan), was used *in situ* to estimate chlorophyll content. The SPAD-502Plus performs quick measurements of the chlorophyll content of leaves without damaging the leaf. Three leaves were selected single plant to form one sample. The Whole healthy leaves were sampled randomly from the plant. The SPAD reading of each tomato leaf was obtained at three locations: (a) about one-third of the leaf length from the petiole, (b) at the midpoint of leaf, and (c) about one-third of the leaf length from the apex. At each location, a measurement was taken on both sides of the leaf vein. The six SPAD readings were averaged to provide a single reading per leaf.

## **Crop morphological data collection**

Crop morphological data were collected on plant height, stem diameter, leaf area, branches, number of flowers per plant, and the number of leaves per plant on a regular basis. Plant height was measured from 30 days after transplanting (DAT) till 105 DAT on 15 days interval. To evaluate the effect of water stress on the

parameters of the plant, stem diameter was measured with calipers. The accuracy of the caliper was  $\pm 0.02$  mm « 100mm). Fruit diameter is also measured by caliper (in cm).

### **Crop Growth stages**

Four growth stages were identified in this study for Tomato variety Thilina. Growth stage 1 is from the establishment to 1<sup>st</sup> flower stage of 15-30 days, Growth stage 2 is from first flower to first fruit set of about 30 days, Growth stage 3 is from Fruit ripening stage to first harvest of 30 days and the Growth stage 4 is from first harvest to the end of harvest of 30 days. Reading of every 15 days interval within each growing stage was calculated for analysis.

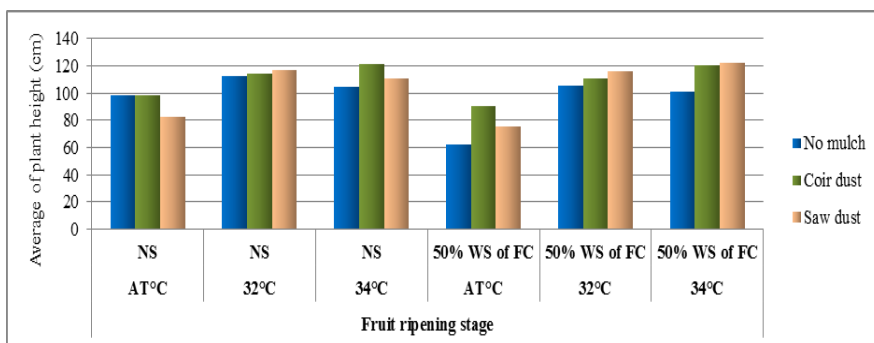
## **Results and Discussion**

### **Temperature and water stress on growth parameters of Tomato**

#### **Plant height**

The plant height varied due to different mulches and temperature at different growth stages irrespective of water stress condition. Mulching has contributed to the moisture conservation in water stress treatments. Therefore, there was no significant difference in the plant height between water stress and no water stress treatments. Figure 1 shows the plant height during fruit ripening stage and the mulching treatment has a significant effect on plant height compared to the no mulched treatments. Coir mulch in 34 °C maximum temperature treatment showed the superior performance in plant height than the control without mulched, indicating mulches had a positive effect on the growth and development of Tomato variety Thilina. The increased plant height in mulched plants may be possibly due to better availability of soil moisture and by reducing the effect of higher temperature.

The slope of the line in the interaction plot for the no mulch condition is steeper than others. It shows that the effect of mulching on plant height was significant ( $p < 0.05$ ) in 32°C maximum temperature in fruit ripening stage.

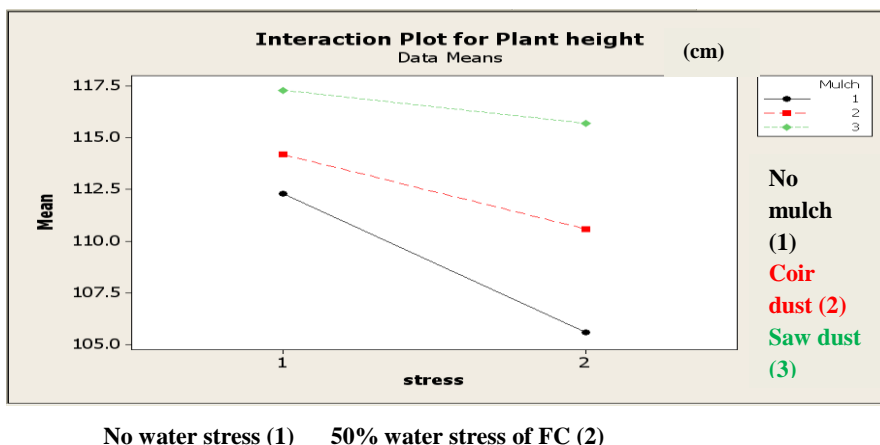


**NS** = No water stress    **WS** = 50% Water stress of FC    **FC** = Field Capacity

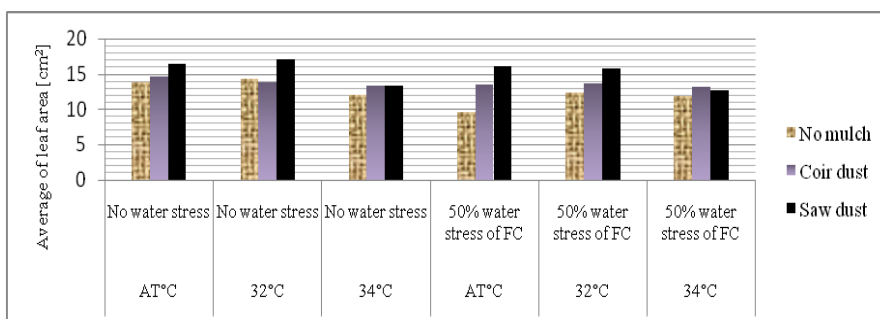
**Figure.1.** Effect of temperature and water stress on average plant height during fruit ripening stage of Tomato variety Thilina grown with two types of mulches.

## Leaf area

The mulches had a significant effect on the leaf area of the plant (Figure 3). The leaf area continually increased with plant age. All the mulches had the positive effect on generating and retaining higher leaf area per plant. The highest leaf area per plant was observed in saw dust mulch in no water stress treatment of (AT °C) ambient temperature. Plants grown in saw dust mulch showed the significantly highest leaf area in both ambient and 32 °C maximum temperature respective of water availability. Plants in control treatment showed the lowest leaf area in both temperature and water stress treatments. It showed that the mulching effect has a significant role in leaf area as the slope of the interaction plot is steeper in no mulch treatments (Figure 4). Favorable weather conditions and moisture of the soil are the important parameters affecting the leaf area of plant. It was reported (Barrs, 1968) that mulched Tomato plants had more leaf area and branches than that of plants without mulch, which supported the present results.



**Figure.2.** Interaction of mulch and temperature plot for plant height in 32 °C maximum temperature in fruit ripening stage.

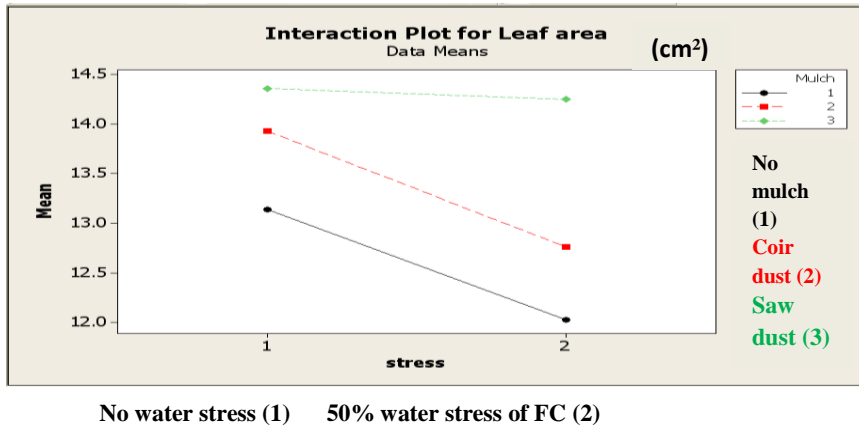


**Figure 3.** Effect of temperature and water stress on average leaf area of Tomato variety Thilina grown with two types of mulches

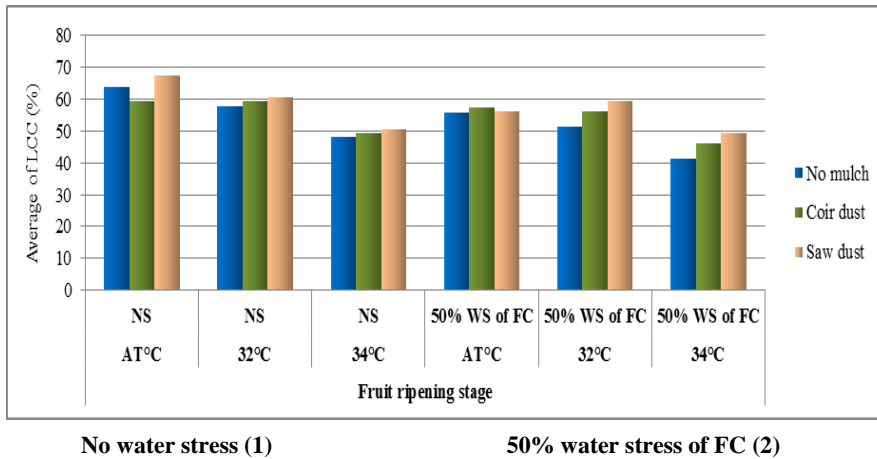
### Leaf chlorophyll content

Chlorophyll concentration has been known as an index for evaluating source strength thus, its decrease under drought stress can be regarded as a non-stomata limiting factor. There are research findings showing the decrease in chlorophyll under drought stress (Kulshreshta *et al.*, 1987). The effect of mulch on leaf chlorophyll content of plants during the fruit ripening stage of Tomato variety Thilina is presented in Figure 5. Results revealed that the plants in mulched treatments have more chlorophyll content than no mulched treatment plants. It is also revealed by the slope of the interaction plot of no mulch treatment (Figure 6) for the 32°C temperature during the fruit ripening stages ( $p < 0.05$ ). Kirnak *et al.*, (2001) showed that the total chlorophyll content in high water stress was

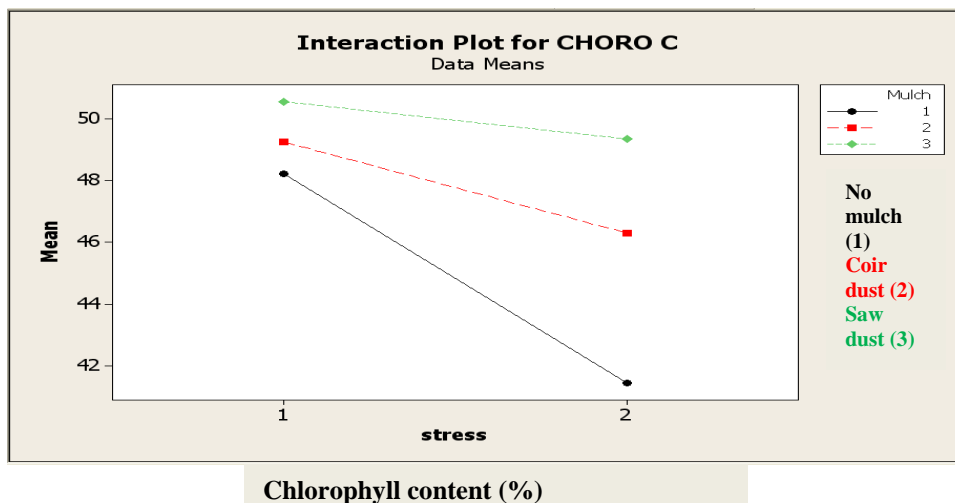
reduced by 55% compared to the control which agrees with present results.



**Figure 4.** Interaction plot for mulch effect on leaf area (cm<sup>2</sup>) in 32°C maximum temperature in fruit ripening stage.



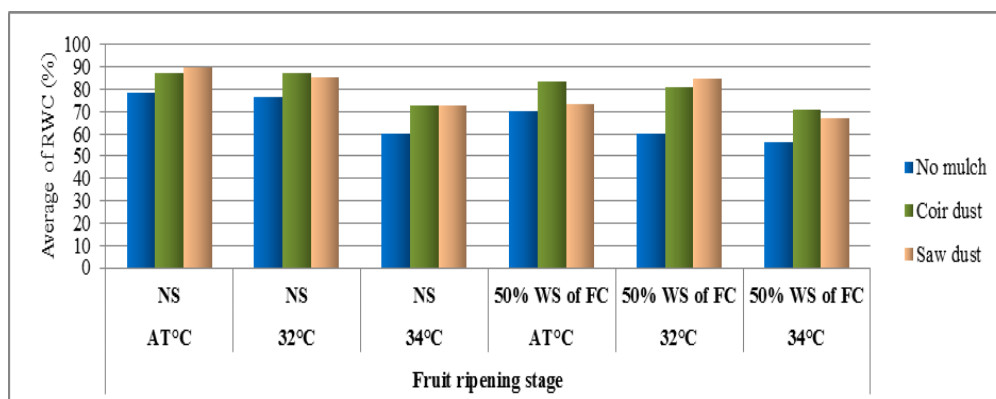
**Figure 5.** Effect of temperature and water stress on chlorophyll content (LCC) of Tomato variety Thilina grown in two types of mulches.



**Figure.6.** Interaction plot for leaf chlorophyll content in 32°C maximum temperature in fruit ripening stage of Tomato variety Thilina.

## Relative Water Content (RWC)

Measurements of water content expressed on a tissue fresh or dry mass basis have been mostly replaced by measurements based on the maximum amount of water a tissue can hold. These measurements are referred to as Relative Water Content (Barrs, 1968). These results show that organic surface mulches can significantly improve the internal water status irrespective of temperature and water stress (Figure 7). No mulch treatments showed the lowest relative water content in all the treatments.

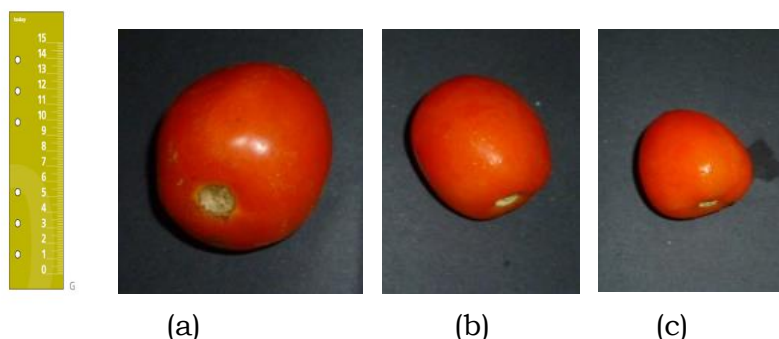


**Figure 7.** Effect of mulch on average relative water content

## **Temperature and water stress on yield parameters of Tomato**

### **Fruit size**

High temperatures, however, often result in smaller fruits (Newton and Sahraoui, 1999). Under ambient temperature with mulching condition in water stress and no water stress treatment (Figure 8a) the average fruit size was larger than the other temperature condition. In 32 °C temperature under no mulch condition with no water stress (Figure 8.b), the average size of the tomato fruit had become smaller. Under 34°C temperature with mulch condition and no water stress (Figure 8.c), the average size of the fruit was the smallest of all. Fruit growth and yield are, like most other developmental processes, primarily dependent on temperature.



**Figure 8.** Temperature and water stress on fruit size (a) ambient temperature with mulching (b) 32°C temperature under no mulch condition with no water stress (c) 34°C temperature with mulch condition and no water stress

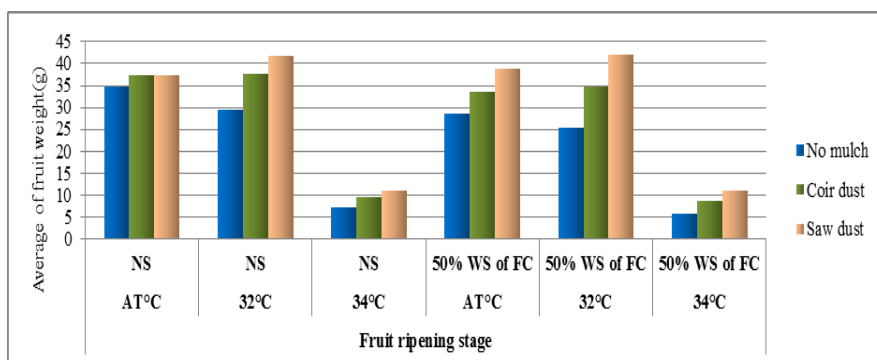
### **Fruit weight**

Fruit weight decreased with increase in temperature irrespective of water availability. Plants grown in an ambient temperature without a water stress showed the highest fruits weight (Figure 9). Fruit weight statistics showed that there is a significantly higher ( $p < 0.05$ ) impact in outdoor ambient temperature compared to 32°C and 34°C temperature ranges inside the poly tunnel. High temperatures, however, often result in smaller fruits. But significant result fruit weight was shown in plants grown with saw dust mulching in all three temperatures. Even the interactive plot on the effect of mulching showed a remarkable effect on the fruit weight of Tomato compared to the other treatments (Figure 10). Sawdust mulch performed well in both water stressed and no water stressed

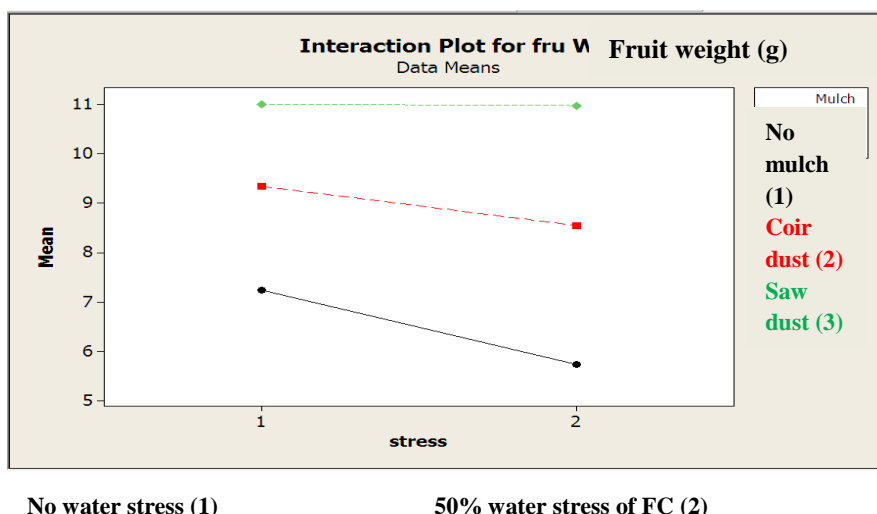


condition irrespective of temperature. However, fruit weight was lowest in 34°C treatments.

Plants grown in an ambient temperature without a water stress showed the highest fruits weight. Fruit weight statistics showed that there is significantly low fruit weight ( $p < 0.05$ ) at 34°C temperature.



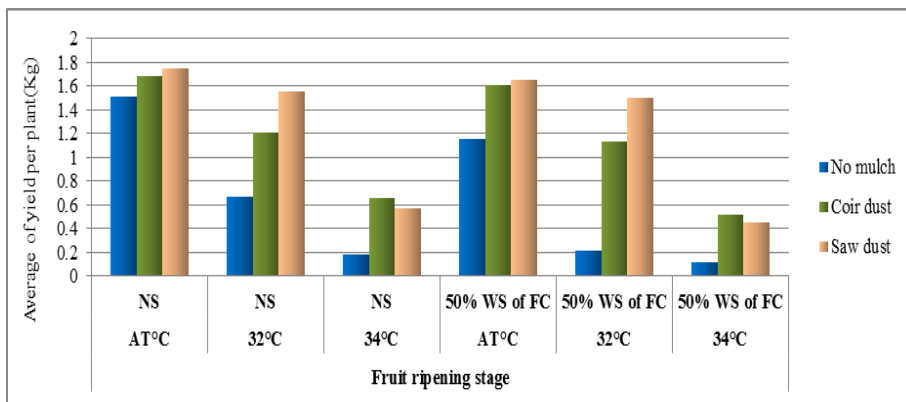
**Figure 9.** Effect of temperature and water stress on average fruit weight during fruit ripening stage of Tomato variety Thilina grown with two types of mulch.



**Figure 10.** Interaction plot for fruit weight in 34°C maximum temperature in Fruit ripening stage.

## Fruit yield

Figure 11 showed that the highest mean yield (1.752 kg/plant) in plant grown in outdoor ambient temperature without water stress and saw dust mulching condition, followed by outdoor grown plant with a imposed water stress and without mulch, showed the lowest mean yield (1.175 kg/plant). The vegetative growth is higher in the controlled environment condition, at 32°C temperature; the yield was reduced from 1.560 kg/plant to 0.215 kg/plant with water stresses and without mulching condition. Further, the yield obtained at 34°C temperature was 0.653 kg/plant and with imposed water stress and without mulch it was further reduced to (0.110 kg/plant). But in the previous research, without mulching only 0.16 kg/plant yield was obtained at 34°C with no water stress (Gunawardena *et al.*, 2011). This study proves that the yield (0.653 kg/plant to 0.570 kg/plant) can be improved with mulching even when the temperature increased up to 34°C due global warming if the plants are maintained with no water stress.



**Figure 11.** Effect of temperature and water stress on average fruit yield during fruit ripening stage of Tomato variety Thilina grown with two types of mulches.

## Conclusion

### Conclusions and Recommendations

According to the results, there is a significant effect of mulch on growth parameters of Tomato plants exposed to water and temperature stresses. Higher temperature treatments with saw dust mulch showed significantly higher plant height. Higher leaf area was shown on 32°C with no water stress condition. The water stress

resulted in significant decreases in chlorophyll content and the leaf relative water content. High temperature stress of 32-34°C could be minimized by using mulches such as saw dust and coir dust. There were significant good growth parameters under saw dust mulch in maximum temperature of 32°C and under coir mulch in 34°C maximum temperature. Agronomic management practices like mulching will help the crop to adjust to the temperature stress due to global warming in the dry zone of Sri Lanka.

There is a significant effect of water and temperature on yield parameters such as fruit weight, fruit yield etc. According to the results, there is little difference between the water stress and no water stress treatment as the mulching has resisted the effect of temperature by conserving moisture in the soil. Therefore, the yield per plant has improved with coir dust mulch compared to the previous study without mulch at 34°C maximum temperature. This study showed that Tomato variety Thilina will not be a successful crop in open field conditions if the temperature rises above 34°C due to global warming. Therefore Tomato variety Thilina could be cultivated in green houses by providing optimum temperature. However, small scale farmers may be able to cultivate Tomato in open field with mulches such as saw dust and coir dust. These findings could be an adaptation measure for farmers growing tomato if the temperature increases due to global warming.

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## **Maternity Legislation in Sri Lanka: Are Women Equal, Special or Different?**

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### **Abstract**

Pregnancy, childbirth and breast feeding are uniquely female experiences. While a woman's role in reproduction fulfills the important social function of ensuring the continuity of the human race, it is also one which challenges her endeavour to enter the public sphere of paid employment. The creation and maintenance of a public and private divide and the setting of norms in the public sphere on the basis of male standards are barriers women have long fought to surmount.

The aim of this paper is to study the laws governing maternity benefits in Sri Lanka, in order to uncover the foundations on which these laws are built. The study is normative in nature, focusing on applicable legislation in Sri Lanka. Therefore it discusses the provisions containing maternity benefits in the Shop and Office Employees Act, the Maternity Benefits Ordinance and the provisions of the Establishment Codes relevant to state sector employees including university employees. The benefits studied are maternity leave, pay, nursing intervals, job security, health and safety of mother and child, paternity benefits and crèche facilities. The paper then critically analyzes and compares the applicable laws. It concludes by highlighting the lack of uniformity among the legislation and investigating the likely rationales for this difference through a feminist lens focusing on the public-private divide, and the 'equality' and 'different' or 'special' approaches.

**Keywords** - Maternity benefits, feminism, maternity benefits

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ordinance, shop and office employees act

## **Introduction**

### **Background of the study**

Since time immemorial, women have been recognized as the primary care givers of children. Women, who in early times did not go to work outside the home, maintained the house, did the daily housework and raised the children.

The modern woman holds a full time job outside her home, and continues to fulfill her traditional role of caring for and raising the family. According to data regarding the first quarter of 2014 collected by the Department of Census and Statistics, 35.5% of the economically active population (i.e. the labour force) of 8.8 million Sri Lankans, were women; 31.6% of the urban sector, 35.9% of the rural sector and 44.1 % of the estate sector employees were female. In the first quarter of 2015 the economically active population increased to 8.9 million and the percentage of women to 36.7%; 35.1% in the urban sector, 36.5% in the rural sector and 46.5% in the estate sector respectively. This data indicates that the female labour force though less than the male, is growing steadily. It also shows that women are actively involved in all the major sectors of employment, though the largest number is employed in the estate sector.

The Labour Survey Annual Report 2014 records female labour force participation as 34.7%. 37.7% of women aged between 20-24 years, 41.5% belonging to the age group 25-29 years and 43.6 % of the age group from 30-34 years were employed in 2014. This indicates that a large portion of the working women were within the child-bearing age.

In the light of the above data it could be assumed that many women will enter motherhood while in employment. It is therefore mandatory that there be sufficient legislation to protect a woman's job during her maternity and to provide her with maternity benefits, primarily maternity leave to help her to cope with her dual role as care giver and employee.

### **Nature and scope of the study**

On a global scale, the entry of woman into the workforce took place without any allowance being made for her then primary social role of child bearer. She was not provided with any special leave entitlement or guarantee of a job on returning after childbirth. Nor

was any monetary support provided during her absence from work to deliver the baby. Thus she entered a space which had until that point of time been a male domain tailored for men with no alterations being made to suit her own femininity.

It is a positive feature that the Sri Lankan legal system has, in this field, as in most others governing the labour force, adopted a pro-employee stance, by providing protected maternity leave to new mothers. Nevertheless, one of the drawbacks of the Sri Lankan law is that there is not one but several laws governing maternity, and that these laws lack uniformity. Thus, a women's leave entitlement differs merely by virtue of the sector to which her employment belongs and women placed in the same position due to pregnancy may be provided different treatment.

This is a situation which the author believes warrants a more critical examination. The objectives of this research are therefore:

- To review the existing laws governing maternity benefits, i.e. The Shop and Office Employment (Regulation of Employment and Remuneration) Act, The Wages Board Ordinance, The Establishment Code and relevant Circulars in Sri Lanka;
- To compare the content of these statutes and uncover the differences between treatment afforded to women in different sectors of employment; and
- To make suggestions for ensuring uniformity among women workers in Sri Lanka.

The author understands that developments in other countries have led to the very concept of leave for child care being broadened to include paternity and parental leave. However, this aspect is beyond the scope of this article which focuses more on studying the laws directly linked to leave granted to women at the time of entry of a new child into the family.

The primary benefit an employed mother-to-be would require is maternity leave to have the child, care for it immediately after birth and time to recover from childbirth. Apart from this, the assurance of her job being held for her pending her return to work and financial support until resumption of work, are also important maternity benefits. Some organizations do go beyond this to provide insurance or medical expenses as well. However, this paper focuses primarily on leave, pay and job security and the welfare of the mother and child.

## **Theoretical framework**

There are many feminist theoretical perspectives from which maternity legislation can be interpreted. The key distinction between the theories stems from the importance placed on the essential nature of femininity in the law-making process. Some of the key theories relevant to this study focus on gender difference in terms of equality, difference or being special. Others locate such distinction in the public-private division while post structural feminists deny a universal female experience. The key elements of the theories used in this paper are discussed below.

### **Equal or different?**

In analyzing the laws governing maternity benefits, the primary question that arises is whether women should be provided special concessions during the period of pregnancy and childbirth. One way to approach this question maybe to emphasize either the equality or the difference between the sexes in the reproduction process.

'Equality feminists' believe that the feminine identity should receive minimal emphasis in the fight for equal rights and equal opportunities in the public domain. 'Equality feminists' such as Phillips (1987) argue that gender differences should be discarded in order to ensure equality of women in the workplace. However, as Guerrina (2001) points out, this approach ignores the inequalities and gendered division of labour in the private sphere and its impact on the public sphere.

'Difference feminists' on the other hand argue that women's needs qua women must be taken into consideration in the formulation of legislation and in decisions governing work policies. Hare-Mustin & Murecek (1994), for example state that the biological difference between the sexes which is prominently highlighted by pregnancy should not be ignored. They point out that male needs and behaviour should not set the norms of workplace policy to the detriment of the special needs of a pregnant woman. Valarie Bryson (1992) criticizes the equality approach which advocates 'sex blind' or 'gender neutral' legislation on the basis that it undermines feminist struggle for recognition based on differences such as maternity.

Guerrina (2001) queries the validity of the 'difference' view which accepts that men and women are different and have different roles in society so that women possess a 'womanly essence'. She sees this as an implicit acceptance of the association between a woman's biological and social functions of reproduction. Advocating an



approach which recognizes equality in difference Guerrina (2001) comments that the role of motherhood, which is the primary role of a woman in the private sphere, must be taken into account in ensuring equality for women in the workplace. Evans (1995) has argued that the dichotomy between 'difference' and 'equal' is as artificial as that created between the 'public' and 'private' sphere and that they should be redefined so that they become congruent, recognizing equality in difference. Guerrina (2001) too advocates this view stating that the very meaning attributed to the terms 'equal' and 'different' is based on gender roles and gendered division of labour.

### **Equal or special?**

In applying these theories of 'equal' or 'different' a key issue is whether pregnancy is unique to women making them 'special' and entitling them to be treated differently. Or as equality feminists argue, does it place them on an equal footing with any employee who becomes temporarily unable to carry out his or her duties and entitle her to treatment equal to such employees? As stated by Vogel (1990) advocates of the 'special' treatment approach such as Krieger and Cooney (1983) believe that real sexual difference constituted by pregnancy makes special treatment necessary to ensure equality. However, Williams (1982) argues that the 'equal' treatment approach is sufficient to entitle pregnant employees, to benefits on the basis of the very real physiological uniqueness of pregnancy which creates burdens on working women which could be compared to other burdensome physiological conditions. However, 'Special' treatment advocates see both the identification of pregnancy as a disability and the acceptance of a male standard of equality as the norm as unacceptable. Finley (1986) argues that where biological differences exist, it must be accepted that women are differently situated. It would appear that those adopting a 'different' and a 'special' stance follow a common line of thinking which contrasts with advocates of 'equality'.

Kay (2013) puts forward a unique proposition when she comments as follows on the two approaches; the equality model recognizes cross sex assimilation as the norm; the difference model 'supports a range of social arrangements from traditional ones, where men and women occupy separate spheres to more androgynous society in which the spheres converge preserving the best characteristics of both sexes'. She then postulates a separate argument viz. that the biological reproductive sexual differences be taken account of and treated as legally significant only when they are used for reproductive purposes. The reproductive differences then are not

considered as part of sexual identity but merely a functional attribute. She argues that the reproductive differences only become relevant when a party engages in reproductive behaviour. Such behaviour is temporary for males but may last for nine months and end only in childbirth in the case of a woman. If male and female co-workers both engage in reproductive behaviour and the male is not affected as a result while the female is, Kay argues that in order to maintain equality of opportunity between them, the female should not suffer any disadvantage not encountered by the male in the workplace.

### **The public-private divide**

As Guerrina (2001) argues, maternity legislation focuses predominantly upon women's rights in the official labour market; This highlights the extent to which legal structures are founded upon, and in turn support, the division between the public and the private sphere. Thus, the scope of maternity legislation is limited to women's position as pregnant workers in the official labour market. This limitation strengthens the illusory division between the political and the domestic sphere and reaffirms the overwhelming power of the political sphere over the domestic domain'.

The fact that women bear children and men do not is according to Finley (1986) the key impediment to women becoming fully integrated into the public world of the workplace and according to Taub and Schneider (1982) the main factor causing discrimination to women in the workplace and maintenance of the ideology of separate spheres. Finley (1982) comments that this child-bearing role may prevent women obtaining economically lucrative jobs and force them back to the workplace sooner than child development policies advocate. She argues that it is necessary to recognize that the private and public spheres are a continuum each affecting and defining the other. Most employment takes the form of eight-hour five-day week jobs, which do not take into consideration the roles expected of mothers in the private sphere but rather reflect traditional male work norms. As Finley argues if 'rights' are replaced with 'responsibilities' maternity leave can cease to be seen as 'special' treatment but be recognized as benefiting men and children as well.

### **Post structural feminism**

Post structural feminists deny the notion of a universal womanly experience. Rhode (1992) for example states, that there is no generic woman nor any monolithic 'woman's point of view'. The power of

gender hierarchies is created and maintained by a traditional definition of woman which disassociates nature and society. The concept of 'woman' is a by-product of a complex set of social and cultural relations. This same is true of maternity and motherhood. As Elam (1990) comments 'woman' is a 'permanently contested site of meaning'. Guerinna (1995) states that though women may experience biological commonalities throughout maternity, 'woman' 'motherhood' and their relationship derives from social networks both in the public and private sphere.

## **Maternity and the economic theory of opportunity cost**

Apart from feminist theories, Baker and Milligan (2008) discuss a few theoretical models of the decision to breastfeed which would also be of relevance in reviewing maternity legislation. Accordingly Roe et al. (1999) and Chatterji and Frick (2005) explain that the opportunity cost of time spent on breastfeeding will rise significantly with the return to work, and predict a clustering of breastfeeding termination just prior to return. If the mother plans to stop breast feeding on return to work and therefore only contemplates a short period of breastfeeding, the fixed costs in equipment and learning may not exceed the short flow of benefits and, this may result in decreased initiation of breastfeeding. These economic theories are based on the assumption that making the decision to stay away from work plays a more important role in the outcome than the decision to breastfeed.

## **Methodology**

This study is normative in nature. It seeks to study the various laws governing maternity in Sri Lanka and the benefits provided to a woman during her period of pregnancy and childbirth from a feminist and economic perspective.

Section 21 of Maternity Benefits Ordinance defines 'maternity benefit' as the amount of money payable to a woman under the provisions of that Ordinance; although Part 1A of the Shop and Office Act is headed with the title 'Maternity Benefits', no definition of the term is to be found within the Act. Therefore, the author has adopted the broader meaning for 'benefit', i.e., encompassing all the benefits conferred on a woman during pregnancy and childbirth, for this paper. Accordingly, the study identifies seven key benefits relevant to pregnancy and childbirth, namely, maternity leave, nursing intervals, welfare of mother and baby, job security, pay, crèche facilities and paternity leave. This paper first analyzes the provisions in the Maternity Benefits Ordinance, the Shop and Office

Employees Act and the Establishment Codes to identify the currently existing laws governing maternity benefits under each of the above headings. These laws are then compared with a view to identifying the consistency of the benefits provided to women working in different sectors. These laws are also compared against international obligations and feminist stances on provision of maternity benefits in order to identify the legislators thought process behind the adoption of specific provisions.

## **Rationale for granting maternity benefits**

Many reasons maybe identified for maternity leave to be provided to mothers. Guerrina (2008) cites three reasons which guide maternity legislation i.e. protection of women's health and safety; broadening women's rights as workers by for example protecting against dismissal during maternity leave; and protection of the 'special' relationship between mother and child.

The needs of the new-born can be seen as another reason for granting maternity leave. The World Health Organization (WHO) and UNICEF both recommend that babies be exclusively breastfed for the first 6 months of their lives (i.e. 180 days) for optimal development, health and growth. WHO states that all needs of a baby for the first 6 months of its life, up to half its needs between 6-12 months and up to one third of its needs during the second year of life can be obtained from breast milk. This WHO statement in 2015 is based on the findings of a study by Kramer and Karuma (2009) which indicates that exclusive breastfeeding of infants with only breast milk, and no other foods or liquids, for six months has several advantages over exclusive breastfeeding for 3-4 months followed by mixed breastfeeding. These advantages include a lower risk of gastrointestinal infection for the baby, more rapid maternal weight loss after birth, and delayed return of menstrual periods.

Studies by Baker and Milligan (2008) and Bick et al. (1988) however, indicate that there is a strong link between return to work and stopping or never breast feeding a baby. Empirical studies by Kurinij et al. (1989) Gielen *et al.* (1991) Lindberg (1996) Visness and Kennedy (1997) and Fein and Roe (1998) further support this view.

The International Labour Organization (ILO) has set out international standards for maternity protection by Maternity Protection Convention (Revised) 1952 (No 103). This was superseded by Maternity Protection Convention 2000 (No 183). However, Sri Lanka has not ratified the 2000 Convention and continues to be bound by that of 1952. According to Article 1, the Convention covers

women employed in industrial undertakings and in non-industrial and agricultural occupations, including women wage earners working at home. Article 3 (2) sets out the minimum period of leave as 12 weeks. Article 3 requires that states provide for additional leave before or after birth if the mother suffers any maternity related illness. Article 4 requires states to provide for maternity benefits sufficient for the full and healthy maintenance of mother and child. Article 5 deals with the requirement for feeding hours while Article 6 prohibits termination of employment during pregnancy. Article 7 provides a ratifying state with the opportunity to exempt itself from applying the convention to certain groups including home workers, domestics and women working in agricultural undertakings other than plantations. However, Sri Lanka has not chosen to exercise this option and all women workers are entitled to its protections.

## **Maternity legislation in Sri Lanka**

The principle laws governing maternity benefits in the private sector of Sri Lanka are the Shop and Office Employees Act No 19 of 1954 and the Maternity Benefits Ordinance No 32 of 1939. The Establishment Code of Sri Lanka is the law applicable to state sector employees. The provisions dealing with maternity benefits in the Code have been amended by Public Administration Circular No 3 of 2005. The Establishment Code applicable to universities as amended by University Grants Commission Circulars is also considered here in light of its applicability to the University Community.

## **Applicability of the laws**

The provisions dealing with maternity benefits under the Shop and Office Employees Act No 19 of 1954 are applicable, by virtue of Section 18(A) to every women working in or in businesses related to shops and offices.

The Maternity Benefits Ordinance No 32 of 1939 covers all “women workers” (other than women employed in or about the business of a shop or an office or a woman whose employment is of a casual nature) who are according to Section 21 of the Ordinance women employed on wages in any trade, whether such wages are calculated by time or by work done or otherwise and whether such contract is expressed or implied, oral or in writing. A trade is further defined by the section to include any industry, business undertaking,

occupation, profession, or calling.

The Establishment Code contains the provisions applicable to pregnant females employed in the public sector or in Statutory Boards or covered by provisions of the Establishment Code (Chapter XII). Leave entitlements for those falling into these categories, are currently set out under Public Administration Circular No. 3/2005 by which Section 18 of the Code has been amended. The maternity benefits available to a pregnant university officer are set out in University Grants Commission Circular No10/2013. This circular reflects the contents of the Establishment Code prior to Public Administration Circular No. 3/2005.

Therefore, it can be seen that different laws apply to pregnant women depending on their place of employment. While this in itself may not be of significance, the variation of entitlements under the different laws does give rise for concern.

As mentioned above, the Maternity Benefits Ordinance clearly excludes employees whose nature of work is casual from the ambit of the Act. Thus, a casual pregnant employee in a factory for example is not legally entitled to any benefits. There is no such restriction in the Shop and Office Employees Act which covers 'every' female person employed in the business of a shop or office.

Section 18 of the Establishment Code and Section 1 (a) of University Grants Commission Circular 10/2013 specifically state that all permanent, temporary, casual and trainee female officers are entitled maternity benefits. Therefore, there is specific mention of casual employees in these two laws.

Thus, while three groups of casual employees are covered by maternity laws, those governed by the Maternity Benefits Ordinance are not provided with any maternity benefits.

It is a common practice to engage employees for long periods of time in casual positions in Sri Lanka and such employees are a vulnerable group of employees. Thus, all employees other than those covered by the Maternity Benefits Ordinance are protected by legislation. However, the exclusion of this category of employees under the Maternity Benefits Ordinance which covers establishments such as garment factories where employees are

predominantly women raises the query on why equals are treated differently.

No laws exist to cover employees such as those in domestic service in private households and home workers. This is despite the ratification of the Maternity Protection Convention (Revised) 1952 (No 103). This appears to validate feminist argument on the public-private divide. Those not within the official labour market, do not appear to be considered worthy of equal rights as fellow workers in the official labour market. This reluctance to recognize work done within homes is a clear reflection of patriarchal values. The continuing maintenance of an artificial distinction between work done in homes and 'work places' and an undervaluing of household work is particularly incomprehensible in a country where migrant workers earnings as housemaids contribute significantly to Sri Lanka's foreign exchange earnings.

### **Maternity leave**

Women employees governed by The Shop and Office Employees Act No 19 of 1954 are as a result of an amendment in 1985 entitled to 84 working days leave - 14 days before confinement and 70 after - with full pay on the birth of the first and second child [Section 18 (B)(2)]; however for subsequent births this is halved to 42 working days i.e. 14 days before confinement and 28 days thereafter [Section 18 (2) (b)]. Any birth, which occurs when the woman has two children living at the time of confinement, will only entitle the mother to 42 working days. Thus, she is entitled to only 42 days on her second delivery if she has twins on her first delivery and 84 on her third if one of her previous children is no longer living at the time of the subsequent delivery. A still birth - that is a foetus of 28 days gestation - entitles the mother to 42 days leave with pay, 14 days prior to confinement and 28 days thereafter.

According to Section 3 of the Maternity Benefits Ordinance a pregnant employee is entitled to 12 weeks (2 weeks before and 10 weeks after confinement) inclusive of holidays (84 calendar days) for the first two births and 6 weeks or 42 calendar days for any subsequent birth if she has two children living. In the event of confinement which does not result in a live birth a woman is entitled to 6 weeks leave. Section 21 defines a confinement as labour

resulting in the issue of a dead child, live child or viable foetus (foetus of at least 28 weeks or when in doubt, 12 inches in length and at least two pounds in weight).

Female officers to whom the Establishment Code applies are entitled according to Section 18, to 84 working days leave with full pay. Section 18:3:1 entitles a mother to another 84 calendar days with half pay 'to look after the child'. Section 18:4:1 provides for another 84 calendar days no pay leave 'only if it is required for the purpose of looking after the child'. All maternity leave entitlements are available for each birth irrespective of the number of births as no limitations are placed on them as in the case of the Maternity Benefits Ordinance and Shop and Office Employees Act. Further Section 18:2:4 provides for six weeks leave in the event of a still birth or birth where the child dies during the first six weeks after its birth.

The University Grants Commission Circular No 10/2013 entitles a pregnant university officer to 84 working days with full pay (i.e. excluding holidays) for each, live, childbirth. In the case of a still birth or the death of a child before 6 weeks from the date of the childbirth, the mother is entitled to 6 weeks paid leave. Apart from the 84 days leave, a woman can take a maximum of six extra months (inclusive of holidays) no pay leave, either if her child is born abnormal and remains in that state at the end of the leave or, if the mother needs further rest due to complications arising from childbirth.

The discussion of the provisions above highlight some sharp contrasts in the laws governing different groups of workers. For example although only working days are considered in calculating the number of days leave granted to women covered by the Shop and Office Employees Act and Establishment Codes, even holidays are included in the calculation for women covered by the Maternity Benefits Ordinance. Thus the latter are likely to enjoy a lesser total number of days than the former.

A serious shortcoming of the maternity leave in Sri Lanka is the difference in the period of leave granted. It is noteworthy that both the Maternity Benefits Ordinance and the Shop and Office Employees Act provide only half the time period for third or



subsequent births; it is only under the Establishment Codes that this period remains the same irrespective of the number of births. When the 42 day period is viewed in the light of the economic theories of Roe et al. (1999) and Chatterji and Frick (2005) it could be pointed out that mothers' are more likely to not initiate breastfeeding or terminate it early in the case of the third and subsequent children. This could lead to serious implications when the WHO and UNICEF recommendation of six months exclusive breastfeeding for babies, is considered. It also places serious constraints on such mothers to provide the best care equally for all their children.

The existing provisions are a clear expression of the acceptance of a public-private divide. The woman's role of child-bearing and rearing has been separated from that of employee and the burden has been cast on the woman to decide whether she is willing to have a third child subject to lesser benefits. This is as Finley (1986) has stated a failure to recognize that the private and public spheres are a continuum each affecting and defining the other. If as she argues 'rights' are replaced with 'responsibilities' maternity leave should cease to be seen as 'special' treatment and be recognized as benefiting society as a whole.

The application of different provisions to women placed in an equal position due to pregnancy is itself inexplicable. The private sector laws appear to be drafted from a purely masculine perspective, which does not appear to understand that though pregnancy itself may have commonalities, each pregnancy and birth is unique carrying its own consequences as postulated by postmodern feminists. If a child dies before the mother has a third baby, she is entitled to a larger number of days than if the first two survive; thus a third baby whose elder sibling dies is privileged above the child whose siblings survive. Thus, third born children are treated differently on the basis of the place of work of their mothers. It is noteworthy that on 23<sup>rd</sup> March 2015, Cabinet approved amendments to the Maternity Benefits Ordinance and the Shop and Office Employees Act removing this anomaly and granting an equal number of days leave. However, the draft bill has not yet been finalized though more than a year has passed since the decision. The author learns that this may be presented to Parliament before the end of the year. The slow progress of these amendments reflects

a lackadaisical attitude towards the many thousands of women who may be denied a benefit which would have a significant impact on both their own lives and those of their families.

Since the University Grants Commission does not appear to have adopted the 2005 Circular and retains the 2004 provisions by its Circular of 2013, further diversity in leave provisions is created. The university employee in comparison to other state sector employees is only entitled to an additional leave of six months on no pay, and this too only if the child is abnormal or the mother's delivery gave rise to complications. This diversity in availability of leave is also problematic when viewed in light of Sri Lanka's obligations under the Maternity Protection Convention 1952 (No 103) to provide 12 weeks maternity leave. The provisions for extension of leave is a salutary feature, but lack of uniformity in application across all sectors once more raises issues as to how pregnancy and childbirth and the needs arising there from can be viewed so diversely.

### **Nursing intervals**

The Shop and Office Employees Act does not provide mothers with nursing intervals after returning to work.

However, according to Section 12B of the Maternity Benefits Ordinance nursing mothers are entitled to two, one hour nursing intervals per day until the child is one year old although the time period maybe reduced to half an hour per interval if the employer provides crèche facilities as the mother would have easy access to the child.

The Establishment Code entitles a mother to leave one hour early once she returns to work after maternity leave till the child is six months old in order to breast feed the child (Section 18:7).

Commission Circular 10/2013 by Section 1 (B) grants a mother two half hour nursing intervals after resumption of duties either till the child reaches one year or for six months whichever occurs earlier.

Thus, a wide disparity is seen with regard to nursing intervals, with women in shops and offices not receiving any concessions for nursing their children. Those in trades and factories receive two hours a day while state employees receive only one hour a day.

Among state sector employees too, a difference can be seen; University staff are entitled to a nursing period till the child is one year old but other state employees only get this benefit until the child is six months.

The WHO recommendations for breastfeeding and the advantages to both mother and child which result from it, clearly dictate that sufficient provisions should exist to encourage this practice. The studies by Milligan (2008), Bick et al. (1988) 1989) Gielen *et al.* (1991) Lindberg (1996) Visness and Kennedy (1997) and Fein and Roe (1998) all indicate that there is a strong link between return to work and stopping or never breastfeeding a baby. Roe et al. (1999) and Chatterji and Frick's (2005) explanation that opportunity cost of time spent on breastfeeding will rise significantly with the return to work, and lead to a cluster of breastfeeding termination just prior to return to work mandate that sufficient opportunity to breastfeed be provided in order to stop this trend. Therefore, in addition to sufficient leave, it is also important to provide incentives to continue breastfeeding after returning to work, and provision of nursing intervals is one such mechanism that can and should be adopted. The nursing intervals may be seen as especially important for women who have more than two children since their period of leave is also of shorter duration.

Thus while the concessions given are salutary, its limited application needs to be addressed. Also the practical value of the time duration given must be considered in light of modern times when many women commute long distances to get to their workplaces and road networks are highly congested. Finley's arguments on the public-private divide hold true with regard to nursing intervals as well. While breastfeeding has by nature been cast on the woman, legislators cannot ignore the special position in which it places her, rendering her different to man.

## **Health and safety of mother and child**

Section 18 (D) (1) of the Shop and Office Employees Act and Section 10 (B) (1) of the Maternity Benefits Ordinance prohibit the employment of a pregnant woman in any work which may be injurious to the woman or her child during the last three months of her pregnancy. Section 18 (D) (2) of the Shop and Office Act and

Section 10 (B) (2) of the Maternity Benefits Ordinance extend this protection to three months after confinement as well so that such women have to be provided safe employment for a total of 6 months - 3 months pre and 3 months post confinement-respectively.

While similar provisions are not seen in the laws governing the state sector, Section 18:6 of the Establishment Code permits a women to arrive for work and leave office half an hour earlier than the normal time from end of the fifth month of pregnancy. A similar provision is seen in Section 1(c) of the circular governing university officers. These are provisions not available to employees in the private sector.

The Maternity Benefits Ordinance contains a prohibition of knowingly employing a woman during the first four weeks after her confinement (Section 2). A similar provision can be found in Section 1 a) (i) of the University Grants Commission Circular and Section 18:2:1 of the Public Administration Circular as well.

Additionally, as discussed above, University Officers may obtain an additional six months no pay leave under section 1(d) (i) and 1 (d) (ii); in situations where the child is in an abnormal condition requiring the mothers personal care and where the mother is suffering due to complications arising from childbirth. State employees can also obtain 84 days on half pay and another 84 days no pay leave if required for the purpose of looking after the child according to Sections 18(3) and 18(4) respectively. Such additional leave is not provided for under the laws applicable to non-state employees.

As discussed under leave provisions, mothers suffering still births are also entitled to leave. Mention of miscarriage is however only found in Section 18:2:4 of Public Administration Circular according to which there is no provision for miscarriage other than the ability for the woman to avail herself of any vacation leave entitlement on submission of a medical certificate. A still birth or birth of a child who dies within six weeks of birth entitles the woman to six weeks paid leave under section 18:2:4 of the above Circular. Section 3(b) (ii) of the Maternity Benefits Ordinance also provides for two weeks pre-confinement and four weeks post confinement where the delivery does not result in a live child. Similarly Section 18(B)(2) provides for 14 days pre-confinement and 28 days post confinement if a live child does not result from the delivery.

Thus, the law contains many provisions protecting the health of both the mother and child. What is once more problematic is the manner in which these laws apply. Clearly it would be of great value if a common code governing all pregnant women was introduced ensuring uniform application.

## **Job security**

Section 10 of the Maternity Benefits Ordinance prohibits the issuance of notice of termination to a woman while she is on maternity related leave. A similar provision exists in Section 18 (F) of the Shop and Office Employees Act

Section 10 (A) (1) of the Maternity Benefits Ordinance protects a woman from dismissal due to pregnancy, confinement or any illness arising there from. Section 10 (A) (2) places the burden of proving that a termination made during pregnancy, confinement or an illness resulting thereof was not a result of these circumstances but due to some other reason, on the employer. Similar provisions exist in Sections 18 (E) (1) and (2) respectively of the Shop and Office Employees Act.

No provisions specifically dealing with termination of services during maternity leave are contained in the University Grants Commission Circular No 10/2013 or Public Administration Circular 4/2005. However, Circular 10/2013 contains a provision applicable when a woman takes additional no pay leave; this provision [Section 1(d) (iv)] provides that a woman should not suffer any constraints in terms of increment of salary, pension or promotion as a result of availing herself of such leave. Section 18:9 of Circular 4/2005 contains a similar provision regarding the use of half pay and no-pay leave.

The guarantee of job security is a laudable feature of the legislation. It may be seen as one instance where the public-private divide has actually been broken down to acknowledge the dual role of women in modern society. It also echoes the view of Kay (2013) that a woman alone should not be discriminated against, due to engaging in reproductive behaviour. Once more however, a lack of uniformity across the laws which needs addressing is noted.

## **Pay during leave period**

As seen in the section dealing with leave, all maternity leave given immediately after the birth of a child is with full pay. Additionally, University and state officers are also provided with half pay and no pay leave, above and beyond the original amount of paid leave.

Section 5 of the Maternity Benefits Ordinance as amended by section 43 of 1985 entitles a woman to full payment during her period of maternity leave, while section 5 (3) enables an employer to provide alternative maternity benefits to women employed on his/her estate in lieu of those set out in the Ordinance. Section 18(C) of the Shop and Office Act also requires the employer to provide full pay for the employee during the period of maternity leave.

Section 18:2:1 of Public Administration Circular 4/2005 entitles a woman to 84 working days on full pay for each live birth and 6 weeks for a still birth or where the child does not survive the first six weeks of birth. In addition, state sector employees can also claim half pay for another 84 days if they need to take care of their children beyond the original leave period during which they were fully paid.

University officers are not entitled to half pay leave. Their entitlement of paid leave is limited to 84 working days for each live birth and six weeks for a still birth or birth of a child who does not survive six weeks according to Circular No 10/2013 (Section 1 (a) (i) and (iv).

The provision of paid leave for the initial period of maternity which is provided across all legislation, once more recognizes the dual role of a woman and the continuum between the public and private spheres. Of course, the limitation of the period of paid leave in the event of the third child under the Maternity Benefits Ordinance and the Shop and Office Employees Act as discussed above limits its efficacy. The limited application of half pay and no pay to specific groups of employees, and the difference in the conditions to which such leave is subject however leads to discrimination among new mothers. It is also questionable as to how many women would utilize this additional leave due to limitation of payment. In an era where

the cost of living requires two incomes for a family to survive, availing oneself of no-pay leave may not be a luxury a young mother could afford. In such a situation, the provision of leave may be of little practical use.

### **Crèche facilities**

Section 12 (A) (1) of the Maternity Benefits Ordinance requires an employer of more than a prescribed number of women workers in any trade to establish and maintain, in accordance with regulations made governing it, a crèche for children under five years of age. Any worker should be allowed to leave her children within that age in the crèche while she is working.

Such a requirement for crèche facilities is not seen in any of the other legislation. A clear application of the public-private divide seems to operate in these cases. No responsibility for the welfare of the child has been cast on the employer. The legislation does not take cognizance of the difficulties of a woman in carrying out her dual roles in the public and private spheres. In the modern nuclear family, one of the greatest problems a woman returning to work after childbirth faces is finding a day care or other safe and affordable facility in which to keep her child while she is at work. The availability of crèches in the workplaces could prevent many women from being forced to make the difficult decision to giving up work once they start a family.

Only the Maternity Benefits Ordinance provides discretion for the employers to provide alternative maternity benefits to those provided by law and also includes provision for regulations to compel employers to provide crèche facilities for children of their employees. This is a salutary provision since the highest number of female employees is seen in the estate sector.

### **Paternity leave**

Section 18 of the Establishment Code as amended by Public Administration Circular 3/2006 has introduced 3 days paternity leave to any permanent, temporary, casual or trainee public officer on the birth of a child to such officer's wife, which has to be used within three months of the birth. The marriage certificate of the

officer and birth certificate of the child are required when applying for this leave. The purpose of providing three days leave has not been specified, and in terms of caring for a new born, it seems meaningless. However, no provisions of paternity leave are found in any of the other legislation and on this basis alone it may be considered a progressive step. Unfortunately however, the role a father is envisaged to play in the child rearing-process appears to be in line with patriarchal thinking; namely that it is limited to the act of procreation and possibly celebrating the birth of the child.

An in depth discussion of the father's role is beyond the scope of the present discussion. However, the lack of any recognition of a role emphasizes the argument that law makers maintain a strict public-private divide in which the role of child-rearing appears to remain vested solely with the female. The distinction between child-bearing and parenting does not appear to have penetrated into the understanding of legislators who still seem to perceive it as an essentially female role.

## **Conclusions**

The above analysis of the maternity legislation in Sri Lanka indicates the wide disparity in content applicable to women governed by the different laws.

Several shortcomings maybe viewed across the legislation; failure to provide benefits to casual workers under the Maternity Benefits Ordinance; lack of legislation covering home workers; lesser number of days leave given to mothers governed by the Maternity Benefits Ordinance and Shop and Office Employees Act having more than two children; non availability of nursing intervals to mothers under the Shop and Office Employees Act; lack of provisions for half pay and no pay leave to women in the private sector; the absence of provision for paternity leave except three days for government employees; and non-inclusion of a requirement to provide crèche facilities except under the Maternity Benefits Ordinance.

What is the reason for this lack of uniformity in laws applicable to women working in the same country? Have different considerations played a role in their formulation? What justifies the fact that employees in the private sector offices, shops and trades enjoy lesser benefits than the state sector employees?



Government employees clearly enjoy the greatest advantage in respect to most benefits. They are entitled to the same number of days leave irrespective of the number of children as well as nursing intervals; they are also entitled to half pay and no pay leave beyond the initial period, enabling a woman to make the choice to stay home in order to breastfeed and care for her baby for a longer period of time. While the limitation in pay may affect a woman's decision whether to avail herself of this leave, the very availability is an advantage women employed in other sectors do not enjoy. In contrast, a woman in a university is only entitled to no pay leave, after the initial leave and this too only on the basis of medical need, so that it is a very limited choice. The non- adoption of the most recent Public Administration Circular by the University Grants Commission too which retains provisions less favourable to women, reflects a lack of understanding of the need to break down the barriers between the public and private sphere and a failure to appreciate the importance of the social role women fulfill.

State sector employees are also the only category of employees entitled to paternity leave. Although the quantum of leave may be questionable it at least makes some token acknowledgement that a father too should play a role in the initial care of a new-born.

In contrast, women governed by the Shop and Office Employees Act and Maternity Benefits Ordinance do not have any additional leave entitlement beyond the initial leave which in itself is halved after the second birth. This is in spite of the fact that the state has by ratifying the Maternity Protection Convention, undertaken to provide sufficient leave and benefits. Since casual employees are not covered under the Maternity Benefits Ordinance, this group is particularly vulnerable; although it may be argued that practical difficulties can arise in applying these benefits to persons whose employment is 'casual' it could prevent a person being terminated due to pregnancy alone and becomes important in the light of practical reality where persons are employed in 'casual' positions for long periods of time. Women in shops and offices alone are not entitled to nursing hours, leading to a situation where a mother having a third child has only 42 days leave with no nursing intervals or provision to take additional no pay or half pay leave even if her child requires special attention.

The reduction in leave provided for delivery of babies beyond the second child may be seen as a policy decision to discourage women from having larger families. It could also be intended to place a limitation of the burden on employers to provide maternity benefits and a reduction of the possibility of losing an employee's services for

long periods if they decide to have large families. However, when the state sector laws provide for an equal number of days irrespective of the number of children and also provides for further leave with half pay and no pay, it raises questions as to the basis on which this stance has been adopted solely for the private sector.

It could also be counter argued that mandatory provision of greater periods of maternity leave and nursing intervals would make women of child-bearing years less attractive to employers who may view them as liabilities. This is especially true of the private sector which is primarily driven by profit. Also discrimination in selecting employees on the basis of sex cannot be challenged in the private sector where the largest numbers are employed, as the constitutional protections are only available against executive and administrative actions. Thus, including broader maternity benefits in laws governing the private sector may indirectly have a negative impact on women during the recruitment process. Only a change in perception of employers that there is no division between public and private spheres will effectively ensure that women benefit fully from maternity legislation. The likelihood of this happening would only increase when more women occupy top positions in organizations.

In Sri Lanka, maternity leave is not seen as 'disability' leave but clearly set out as maternity leave. Therefore, it may be argued that the basis of maternity benefits is not 'equality' but 'difference' or being 'special'. Nevertheless, it would appear that Guerrina's (2008) argument that maternity legislation is determined by the official labour market is affirmed by the laws governing the private sector. For example, the halving of maternity leave after the second child is a clear failure to recognize the 'special' nature of pregnancy. It contradicts all laws of nature applicable to the mother and child, and can only be understood in the light of the requirements of the official labour market. The profit driven private sector appears to maintain a sharp public-private divide and does not appear to make allowance for the broader social role women play through reproduction. The standard male norm is applied to women so that upon her resumption of duties, no provisions exist to enable her to balance her dual roles as employee plus mother and care giver. The pre-existing norm that men played no active role as care giver in the private sphere is perpetuated through lack of any mechanism to ensure his involvement in raising the family; at the same time this same 'equal' standard is applied to women ignoring the reality of her dual role. This reaffirms Finley's (1982) argument that the standard is set based on traditional male work norms.

The artificial division between the public and private spheres is seen across all laws dealing with maternity benefits. The role of child rearing is still primarily cast on the woman in Sri Lanka, and legislation has done little to change this by providing meaningful parental or paternity leave. Nor has it evolved to remove barriers women face and help them fulfil their dual roles by providing crèches, or acceptable maternity leave and nursing hours.

It is therefore, the author's contention that though the Sri Lankan legal framework, by providing protected and paid maternity leave has given some measure of protection to women, the lack of uniformity among the laws has created difference among women who are equally situated. Each law dealing with maternity benefits reflects a different legislative intention so that the maternity laws taken as a whole, lack uniformity and discriminate employees of different sectors on no justifiable ground. Therefore, a uniform law applicable to all employees needs to be enacted to address this situation and ensure that all women are given equal benefits to successfully establish a continuum between their home and work lives.

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## **Life with Lost Voice: An Exploration of the Experiences of Patients with Total Laryngectomy**

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### **Abstract**

Voice plays one of the most crucial roles in human communication. As total laryngectomy is the surgical removal of larynx and surrounding structures it causes to lose the voice. The purpose of this study is to explore the experiences of patients with Laryngectomy among the members of Laryngectomies' Association of National Hospital of Sri Lanka (NHSL). Purposefully selected 15 patients with laryngectomy were recruited using purposive sampling method for this qualitative phenomenological study. Data was collected during a one month period by using semi structured interviews. Data was analyzed by the thematic analysis method. The study findings revealed that the patients with laryngectomy faced major changes in their lifestyle due to altered airway such as loss of voice, body image concerns, and challenges with eating and communicating. The findings further provided evidences related to the support of the family, friends and health care professionals which was critical for successful transition during the stressful adjusting period. Therefore, exploring experiences of patients with laryngectomy will help to provide better care for them and lead to enhance their quality of life.

**Keywords:** Experiences, total laryngectomy, laryngectomies.

### **Introduction**

Total Laryngectomy is the surgical removal of the whole larynx and surrounding structures. Partial Laryngectomy, supraglottic laryngectomy, and hemi-laryngectomy are the other main types of laryngectomy. Cancer of the larynx is the most common cause for laryngectomy and total laryngectomy is the final solution that ends

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in most cases (Smeltzer, Bare, Hinkle, & Cheever, 2010). As a result of total laryngectomy, patients mainly experience loss of voice. Loss of voice creates emotional and social changes that may result in withdrawal symptoms and depression. The reactions of the other persons from the society also have a significant impact on these patients' day today life (Happ, Roesch, & Kagan, 2004).

Patients with laryngectomy confront such experiences, because of the increasing amount of cancer situations in respiratory system. More than 450,000 new cases of cancer of the head and neck are diagnosed each year (Donnelly, Gavin, & Comber, 2009). Patients, whose tumors are not eradicated by radiation, generally are subjected to surgery to control the disease (Farrand & Duncan, 2007). Total laryngectomy is undertaken in 50% of those patients (Donnelly *et al.*, 2009).

Patients with total laryngectomy reported mainly the functional and psychological difficulties as their experiences (Noonan & Hegarty, 2010; Risberg-Berlin, Ryden, Moller, & Finizi, 2009; Farrand & Duncan, 2007). The functional difficulties included alteration in swallowing, excessive secretions, speech difficulties, weakness of neck muscles, breathing difficulties and altered energy levels. The psychological concerns included descriptions of depression, regret, and problems with personal resolve.

The study of Bien *et al.*, (2008), focused on voice rehabilitation after laryngectomy and found that the methods used for communication verbally in a laryngeal person were very difficult and very important to do in preserving the breath and swallowing. Esophageal speech, dynamic phantom shunt and external pneumatic electric devices were the methods used by researchers. In that, 1078 (64%) were willing to obtain a speaking method. 403 (24%) of the sample would like to have a speaking method after educating them. Ninety seven (5.8%) of them were not willing to use a device due to age, handling difficulties and economic difficulties.

Further Chaves *et al.*, (2012) conducted an observational study with 15 patients, focusing on the limits on quality of life in communication after total laryngectomy. The results showed that the majority compromises the quality of life in communication, but some suggesting good quality of life. It means important limitations of a personal and social nature due to poor communication with their peers. Thus, there is a need for multidisciplinary interventions that aim to minimize the entrapment of negative impact on people



communicating among these patients.

Nakayama *et al.*, (2008) conducted a study in Japan with 50 laryngectomy patients and found many post-operative complications. Respiratory problems were more significant among their complications. According to the authors, the most common cause of air way obstructions or inadequate breathing was intra operative anatomical disfigurations of the throat and pharynx. However, they have not explained how it started, feelings of the patients, when it occurs commonly and how they managed it. A study on physical and psychosocial consequence of total laryngectomy was conducted with 59 patients by Hilgers *et al.*, (1990). They had shown that it is high among the participants who suffered in high sputum production, cough and forced expectoration, needed to clean the airway more than 5 times per day and needed for more frequent stoma care. This interesting study focused strictly on patients' experiences and the findings showed that how it drastically affected the respiratory system.

Findings of the descriptive study done by Risberg-Berlin *et al.*, (2009) identified the effects of total laryngectomy on olfactory function, health-related quality of life, and communication. Patients who were successfully rehabilitated concerning olfaction and communication, had an overall feeling of good and less mental distress. It showed that the demand for successful rehabilitation is helpful to patients with laryngectomy to overcome these barriers.

According to the literature, even most of the researches addressed to the patients undergoing laryngectomy surgery were focused on the inpatients treatment and recovery process. Little has been studied after they reintegrate into the community. Among these, most studies were done in developed countries than developing countries. However, in the Sri Lankan context, literature related to patients with laryngectomy has not been adequately identified. As Sri Lanka is a developing country with limited resources and specific cultural groups, their experiences of patients with laryngectomy may be significant and of paramount importance. Hence, the main purpose of this study was to explore the experiences of patients with Laryngectomy among the members of Laryngectomies' Association of National Hospital of Sri Lanka (NHSL).

## **Methodology**

A qualitative phenomenological design was utilized in this study. It is best to explore the day to day lived experiences of participants and it recognized how people perceive and talk about their experiences (Hancock, 1998; Lester, 2007; Marriam, 2009). A qualitative

approach is also important to understand how people make sense of their experiences (Merriam, 2009).

## **Study Settings and Participants**

The participants of this study were patients with total laryngectomy from the Laryngectomies' Association; the sole community for patients with laryngectomy in the country at the National Hospital of Sri Lanka (NHSL). The study was carried out between December 2013 and January 2014. Fifteen patients who had lost their voice with the total laryngectomy surgery were recruited using purposive sampling method. Thirteen males and two females who had more than two years experiences after total laryngectomy surgery were considered as inclusion criteria for this selection. The patients with speaking valves were excluded from the study. All of them were using electronic devices after this surgery for communication with others. Willingness to discuss their own feelings and ability to sign an informed consent were also considered as they were able to share their experiences related to their new life with laryngectomy.

## **Ethical Consideration**

Ethics approval was granted from the ethical approval committee at the NHSL and administrative clearance was also obtained from the NHSL authorities. All participants were kept fully informed of the purposes, benefits and potential risks of the study. Written informed consent was obtained from each voluntary participant notifying them of the ability to withdraw from the study at any time without any penalty. Anonymity and confidentiality were assured by securing the information only among the research team and by labeling each patient with a specific code for collected data.

## **Data collection**

The research tool was a theme list that facilitated to conduct face to face semi structured interviews in their mother tongue. It was validated by using reviewed literature and finalized with expert opinion (Polit & Beck, 2013). A translator was used for Tamil and Muslim patients (Polit & Beck, 2013). A theme list was utilized to guide the interview which lasted for 30 to 45 minutes. Theme list or inventory of topics helped to cover all relevant issues such as physiological difficulties as well as psychological discomforts that required investigating. On the other hand, this theme list did not have direct questions but it acted as a reminder or a guide

regarding the topics that needed to be considered while interviewing by the interviewer. Supplementary questions such as “*What; How; and Can you.....*” were added in order to encourage participants to describe their experiences in more detail (Burns & Grove, 2005). To maintain the consistency and accuracy of the data, first author conducted the all interviews.

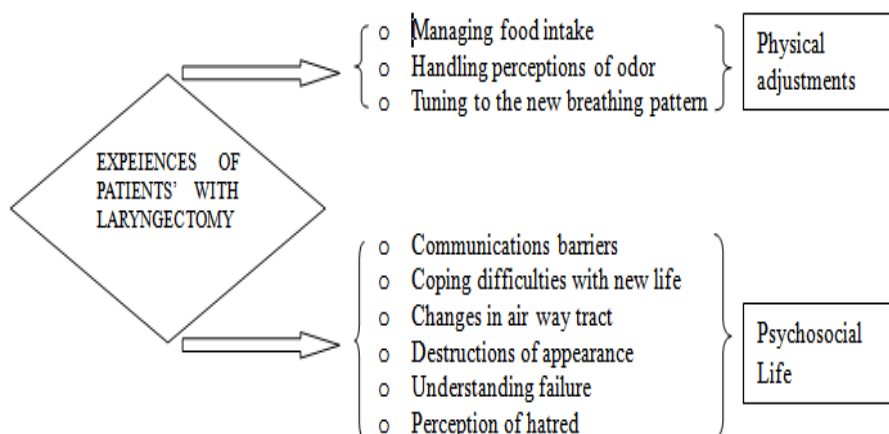
Family members or friends were not presented during the interviews, which allowed participants to talk freely about their experiences without bias. The researchers were able to explore their most valuable experiences during the interview avoiding confusion of participants. Mental stressors and physical tiredness of participants were minimized by providing a calm and quiet environment, flexibility of time and respecting them. Interview skills like keeping silent, listening, making encouraging noises (e.g.: ‘Mmmm’) and looking interested (Boyce & Neale, 2006) were maintained during the interviews. The high quality audio and video tape recorders were used for collecting data to maximize the accuracy of the information. The researchers were more concerned about the nonverbal clues used by the participants (Polit & Beck, 2010). The participants’ body language and comfort level were observed closely during the interview process.

## **Data analysis**

Qualitative data, collected on the digital recorders during the interview, were analyzed according to thematic analysis (Hycner, 1985). For this, several steps of Burns and Grove (2005) have been followed such as transcribed into text with several reviews, clustered, coded according to their common features, and derived sub themes followed with general themes. To maintain the validity of the study, each transcription was reviewed by interviewers to come to an agreement on the extracted themes. Member checks were done to maintain the trustworthiness of the study.

## **Findings**

The 15 participants were interviewed for this study. Participants were above 35 years and below 80 years. From that 13 were Sinhalese, one was Muslim and one was Tamil. All participants were literate and represent below provinces eastern, central, north central, north, and western. According to the findings of the study, laryngectomy patients face various difficulties and these can be categorized into two major themes. Using the generated nine sub themes and two major themes with the analysis process, a model was developed illustrating the laryngectomy patients’ experiences with their new life (Figure 1).



**Figure 1.** Experiences of patient with laryngectomy

## Physical Adjustments

Whatever the type of laryngectomy that the patients had undergone, all of them experienced physical changes after the surgery such as difficulties of food intake, difficulties in smelling, and especially difficulties in breathing due to loss of the larynx or the vocal tube. Participants of the study highlighted that they had to face various problems with physical changes such as difficulties of swallowing, smelling and breathing after a laryngectomy surgery. However, these were regulated by themselves with time. While such personal changes are often difficult to express, the interviews reflected a variety of personal impacts on this as;

*“I often eat rice with much gravy. I want more curry. I don’t like to eat at cafeterias and outside hotels or restaurants. Because if something occurs; I mean cough or respiratory problem it is a big issue. So I drink a milk packet and go home to eat. If the cough starts I can’t manage it alone. Need others help” (Participant M).*

Patients experienced difficulties with odor. They were not in a position to feel the odor. One participant expressed handling perception of odor like this;

*“After this operation sometimes I don’t feel some fragrances such as my perfume or some foods. But I don’t worry. Though I can’t smell I can do so many things?” (Participant B).*

After the laryngectomy surgery most of patients were suffering from breathing difficulties adjusting to new life. Such feeling of turning to new breathing pattern was expressed as follows;

*“After one month I could breathe effectively without the help of oxygen machine.... Step by step I used to tolerate and ignore some difficulties like coughing, nasal discharges and high frequency in breathing patterns.”(Participant A).*

## **Psychosocial Life**

The function of making sounds is performed by the larynx and the vocal cords. When a person loses parts or all of these structures, it can cause difficulties or they can lose the ability to speak. As a result, communication barriers were the main psychosocial experiences reported.

*“I can see well. I can here very well. I feel everything as much as you all. But I feel no need to live without my voice” (Participant A).*

*“I can’t express my feelings to my wife as it is. Also I can’t go close to my children as I wish. I live with all these sorrows till my death. The biggest sadness was my wife also can’t understand me. I have a big fear that I will try to think of suicide again if I have to face intolerance further. It is only fear I have. I don’t like to do so” (Participant A).*

*“It was a dam shame than the inability to speak. I didn’t prefer to talk even with you madam. Actually some looks at us very unpleasantly when we talk with this machine. People are not interest in this rough voice. Just like a Robot. When we talk others look at us specially. Those days I thought even to suicide. I felt no point to live without the voice” (Participant B).*

Difficulties in coping with new life were also a major psychosocial aspect among patients with laryngectomy due to new communication patterns. They might get angry as they were not in a position to communicate well with their family members. Participants reported this as;

*“Those days I was so aggressive. Even the family members couldn’t understand what I say. One day I threw my plate and it was broken. My daughter was also injured with this incident.” (Participant H)*

*“I went to a shop to buy some goods. When I just get on to the*

*shop the owner shouted on me and asked to his helper, give something to this beggar and ask him to don't come again. There is no more to give you again. Madam, I can't speak properly. That is true. But I can hear very well. What will think if you were me? I felt so sad. But I pretend I was deaf and I wrote my need in a paper and gave it with money. He was upset. Then he did his job and smile with me. But that was not the thing should be happened.” (Patient B).*

Patients with Laryngectomy suffered severe cough, high sputum production and dryness of the respiratory tract when they were coping with the new life. Furthermore, they were dealing with the problem of coughing and also the problem with their out ward appearance influencing their lifestyle. They always sought to cover it with modifications to their dresses. Participants revealed this situation as;

*“I am always covering my neck with this handkerchief and I always bring this papers (showing paper tissues) in my pocket to clean this (showing his neck opening, which is full of secretions)” (Participant N).*

*“Earlier, always I used to wear trouser and T-shirt. But now I have to use this towel to cover this opening. So I can't wear any types of T-shirts. The neck button is needed to cover the lower part of the neck with this handkerchief. So many things have to think before wear, eat, and go somewhere. This is our fate.....” (Participant E).*

Additionally, the impression of the community for chronically ill patients like patients with laryngectomy is poor. From the interviews of participants' perception of hatred in their current life were revealed as;

*“People in my area use some names such as “old man with a hole on the neck” “robot man” and “man speaking with machine”. I do not like to go out because of these names”. (Participant J.)*

*“When we talk with this machine young crowd and high class ladies cover their ears with fingers and looks at us like as animals” (Participant C and Participant J).*

Participants were also worried about the inability to express their feelings. They highlighted that it was a big problem and a negative experience after surgery. So the interviewed participants' experiences of difficulties were being understood by others in the society and their hatredness towards them was revealed as;

*“Can I speak as they do? But anyone doesn’t understand it. It is o.k. if we have any advantage by explaining our difficulties. Do you think will they help us with even ten rupees? No never. They just asked for their interest and fun. If we meet on the next day they even don’t know who we are. That’s the way (Participant B and Participant F).*

*“I went to take few documents from our one of the government office and that man told me to come on next day because his spectacles were forgotten in somewhere. Man told me I can’t understand your language perfectly. So you have to write it sometimes. But today I can’t read your words without my specs. Come.... Come.... on tomorrow. I will try. Then what can I do without scolding him? Is this the way the society was care on us. But this is a Buddhist’s country” (Participant H).*

The patients with laryngectomy have a negative impression of society. So they try to hide from the society due to above factors and their special needs such as semisolid food requirements, severe cough during meals and slow oral intake of foods.

## **Discussion**

The study findings showed both positive and negative experiences of patient with laryngectomy. There were two main themes which were derived from the qualitative data of the patients with laryngectomy with relation to physiological and psychological experiences.

These patients have no choice related to their difficulties. However, they want to learn how to live with the effects of laryngectomy surgery which results in a disruption between the upper and the lower airways causing changes in smelling, breathing, swallowing and the loss of a normal voice (Risberg-Berlin *et al.*, 2009; Green *et al.*, 2007; Chaves *et al.*, 2012).

The participants experienced the challenges in finding support and information on self-management of day today airway issues integrating to the new life. They gradually adapted to a new breathing pattern with high frequency in breathing, nasal discharge and coughing. Beitler, *et al.* (2010), Risberg-Berlin, *et al.* (2009), and Noonan and Hergerty (2010) identified these difficulties in breathing

influence on living with an altered airway. The current study further revealed that these changes have significant impact on the patient, their families and the social life of family members.

These study findings described the negative impact of loss of smell and its effect on eating. Dropkin (1997) also concluded that a total laryngectomy produced significant changes in factors related to eating. It can affect nutritional intake and quality of life. The findings of the study further highlighted that swelling, dry mouth, high sputum production interfere with their usual eating patterns (Decotte *et al.*, 2010; Nakayama *et al.*, 2010).

The study findings have revealed that the communication was the major challenge for the patient with laryngectomy. The biggest fear for them was facing the public as well as maintaining interrelationship with others (Risberg-Berlin, *et al* 2009; Chaves, *et al.*, 2012; Green, *et al.*, 2007). They felt angry when they could not communicate properly. Laryngeal cancer is rare for a small community, and patients can feel very isolated and alone when they are the only patient with these challenges. Participants of this study further highlighted that the experiences alter their new life and negatively affected their quality of life (Risberg-Berlin, *et al.*, 2009; Chaves, *et al.*, 2012; Green, *et al.*, 2007).

According to the study findings, patients with laryngectomy experienced high sputum production and dryness of the respiratory tract. Furthermore they were dealing with the problem of coughing. With these all difficulties their out ward appearance influenced their lifestyle. As people look at them in a different way, they always sought to cover it with modifications to their dresses (Decotte *et al.*, 2010; Nakayama *et al.*, 2010).

Patient with laryngectomy often complain about negative attitudes of others upon them, which may cause poor quality of life (Nakayama & Okamoto, 2008). Body image also affects the emotional status of the patients. It appears due to the influence by others' negative attitudes, and bad expressions. This type of attitudes may have increased their physical symptoms. Similarly, their social activities also seem to be diminishing due to these negative attitudes of the community. It may cause poor quality of life after laryngectomy (Dyer & Powell, 2012).



## **Conclusion**

Most patients with laryngectomy suffer problems with communication, smelling, breathing, swallowing and fear of facing of the public. The robotic sound which comes out from the device that the participants use for communicating with others is the major barrier and the biggest fear for them in facing the public as well as maintaining interrelationship with others. Therefore, developing more versatile speaking devices for a low cost is essential. Patients with laryngectomy often complain about a negative attitude of others upon them. Emotional status of the patients appears to be influenced by others' negative attitudes, bad expressions, and these attitudes may have increased their physical symptoms. Similarly, their social activities also seem to be diminishing due to these negative attitudes of the community, which may cause poor quality of life after laryngectomy. Therefore, it is recommended that educational programs need to be established through health care workers to improve awareness among the general public regarding cancers of the larynx since it will help with early diagnosis of cancer. It is also important to ensure the public awareness on this surgery, its consequents and especially for the benefit of prospective patients with laryngectomy, regarding what to expect and how to manage the physical and psychosocial changes after laryngectomy. This will improve their quality of life and will create a harmonious living status for patients with laryngectomy within the society. Moreover, further research on the topic is needed to expand and corroborate the findings of this study, to make better improvements in laryngectomy patients' quality of life, and developing comparatively better speech devices for them.

## **Acknowledgement**

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## **Effects of Global Warming Simulated Temperature and Water Stress on Fruit Quality of Tomato (*Lycopersicum esculantum*) Var. Rajitha**

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### **Abstract**

Experiments were conducted in the temperature regulated poly-tunnels for five consecutive growing seasons at the Open University of Sri Lanka to evaluate the impact of the enhanced temperature and water stress due to Global warming on marketable fruit quality. Split plot experiment based on complete randomized design with 10 replicates was applied as experimental design. The plants were grown in pots, and the main plot included two moisture levels (No water stress, 50% water stress from the field capacity) and sub plots contained 3 different temperature regimes (34°C maximum temperature / 32°C maximum temperature / ambient temperature). Experiments were repeated for 3 seasons to replicate temperature effect. The combination effect of water stress and temperature stress proved to be a significant drawback for tomato yield and marketable fruit quality such as colour, shape, soluble solids content, pH and sugar acid ratio. Mealy bug attack too was very significant in high temperature poly tunnel experiment which affected the marketable fruit quality. Therefore, tomato variety Rajitha could not be a successful open field crop in the dry zone of Sri Lanka if temperature is increased due to global warming. But tomato could be cultivated under green houses by providing adequate water and required soil temperature.

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**Keywords:** Tomato, temperature stress, water stress, quality parameters

## Introduction

Environmental stress is the primary cause of crop losses worldwide, reducing average yields for most major crops by more than 50% (Boyer, 1982; Bray *et al.*, 2000). The tropical vegetable production environment is a mixture of conditions that varies with season and region. Climatic changes will influence the severity of environmental stress imposed on vegetable crops. Moreover, increasing temperatures, reduced irrigation water availability, flooding, and salinity will be major limiting factors in sustaining and increasing vegetable productivity (Anon, 2005). Extreme climatic conditions will also negatively impact soil fertility and increase soil erosion. Thus, additional fertilizer application or improved nutrient-use efficiency of crops will be needed to maintain productivity or harness the potential for enhanced crop growth due to increased atmospheric CO<sub>2</sub>. The response of plants to environmental stresses depends on the plant developmental stage and the length and severity of the stress (Bray *et al.*, 2002). Plants may respond similarly to avoid one or more stresses through morphological or biochemical mechanisms (Capiati *et al.*, 2006). Environmental interactions may make the stress response of plants more complex or influence the degree of impact of climate change. Measures to adapt to these climate change-induced stresses are critical for sustainable tropical vegetable production.

Due to global warming, the temperatures are expected to increase over the present limits at a variable rate. Simultaneously, the water demand of the crops will also increase. Ghazala *et al.* (2010) computed the future water requirement of the crops generally grown in different climatic zones of Pakistan and tested three different enhancements (1°C, 2°C and 3°C) in temperature. They found an average increase in crop water demand as 11%, 19%, and 29% respectively. However, the crops need almost double the amount of water at 2°C increase in temperatures at higher elevation agricultural plains of northern and western mountains.

Tomato needs a controlled supply of water throughout the growing period for optimal quality and higher yield. Imposing water stress in vegetative and ripening stages means a certain amount of water may be saved. But tomatoes are very sensitive to water deficits during and immediately after transplanting, at flowering and during fruit development (Doorenbos and Kassam, 1979). Tomatoes consume water at a lower rate at the beginning of growth and then increase gradually until flowering, after which they reach maximum usage during the peak of fruit ripening. Water consumption remains constant until the onset of ripening after which, in determinate varieties, it decreases (Fisher and Nei, 1990). The approximate range of seasonal ET for tomatoes is 300 mm to 600 mm. This seasonal value takes into account the crop characteristics, time of planting, and stage of crop development and general climatic conditions (Doorenbos and Kassam, 1979).

Heat stress (HS) is one of the most important constraints on crop production that adversely affects the vegetative and reproductive processes of tomato and ultimately reduces yield and fruit quality. High temperature condition strongly affected the vegetative and reproductive organs and tissues of tomato plants for all cultivars (Abdul-Baki, 1991).

Moreover, a number of explanations have been offered for the poor reproductive performance of tomatoes at high temperatures. These include reduced or abnormal pollen production, abnormal development of the female reproductive tissues, hormonal imbalances, low levels of carbohydrates, and lack of pollination (Bale *et al*, 1994). Abdalla and Verkerk (1968) have reported that high temperatures affect several physiological and biochemical processes of tomato plants, which finally effect on yield reduction.

Abdul-Baki, (1991) reported that the heat shock treatment has no positive effect on the vegetative and reproductive development and the hope that heat shock treatment would be beneficial for Tomato plants, particularly for the reproductive development at high temperatures was not fulfilled. This is in agreement with Abdul-baki (1991) who observed and suggested that heat shock on proteins have little to do with the reproductive stage. Also the plants in our experiments were well irrigated. Cutler *et al.*, (1980) reported that Histamine proteins in soybean might accumulate under hot field

conditions for drought plants but not for irrigated plants. Until now, the scientific information on the effect of environmental stresses on vegetables is limited. There is a need to do more research on how vegetable crops are affected by increased abiotic stresses as a direct potential threat from climate change (Capiati *et al.*, 2006).

Therefore, this study was designed to identify the effect of simulated temperature and water stress on quality of fruits produced by tomato plants (var. Rajitha) to understand the effect of global warming.

## **Methodology**

### **Field Experiment**

The experiment was carried out in the two temperature regulated poly tunnels in order to mimic the global warming situations. Poly tunnels were installed at the Open University of Sri Lanka, Nawala, Nugegoda and the experiment was carried out during the period from 2012 to 2014. Thermostats and ventilation fans were installed in each poly tunnel and the temperature was set for 32°C and 34°C as maximum temperatures. These temperatures were selected based on IPCC result on global climate (IPCC, 2007) and the HadCM3 predictions of Sri Lankan air temperature in 2050 for A2 scenario of IPCC (De Silva *et al.*, 2007 and De Silva, 2006). When the temperature inside the poly tunnel increases above the maximum set temperature the ventilation fans start to operate automatically until the temperature is reduced to the maximum set temperature in the thermostat. The poly tunnel was made with polyvinyl chloride (PVC) sheet of 120 micron gauge to have more than 90% transmittance of light and semi-circular elongated in shape with open space at the top only to facilitate the natural circulation of air. Temperature and relative humidity were measured continuously. The basic structure of the poly tunnel was fabricated with galvanized iron (GI) pipe and installed in the experimental field. Experiments were repeated five times in order to replicate the temperature and the tunnel effect.

### **Water application**

Each pot (1' x 1' in dimension) was filled with 5kg of air dried reddish brown earth mixed with compost soil. Other recommended



agronomic practices of DOA for Tomato (var.Rajitha) were followed. Two water regimes were imposed which were well-watered treatment at field capacity and water stress imposed by reducing the soil water content until 50% of the field capacity level.

Soil moisture was determined prior to each irrigation daily and daily rainfall and pan evaporation data were recorded. Soil bulk density was measured to calculate volumetric water content of soil. The upper limit (field capacity) and the lower limit (permanent wilting point) of the available soil moisture contents of volumetric basis were considered as 28% and 16% respectively.

Soil field capacity was calculated on soil dry weight basis. Water stress treatments were imposed when the plants were established at 2 weeks of age of the plants. Only the deficit amount of moisture was added to the root zone to attain field capacity. Before starting addition of water, tensiometer was fixed to the soil of the each pot polyethylene encircled root zone.

### **Relative humidity (RH)**

Relative humidity was measured daily with RH meter to maintain the relative humidity changes inside the poly tunnel and the outside to keep the environmental condition uniform. But, there were no significant differences in RH observed in the inside and outside environment although elevated day time air temperatures in the poly tunnel resulted in higher partial pressure of water. This condition was maintained with the opening of the upper top which helped maintain the same water vapor concentration compared to the outside.

### **Experimental Design**

The experiment was laid out in Split Plot experiment based on Complete Randomized Design (CRD) with ten replicates for the main plot treatment. Main plot included two different soil moisture conditions such as field capacity (no water stress) and 50% of the field capacity level (water stress) and sub plots contained 3 different temperature regimes such as 34°C maximum temperature poly tunnel, 32°C maximum temperature poly tunnel and ambient temperature at open space.

## Estimating Qualitative Parameters of Tomato Fruits

Five randomly selected ripe fruits (judged by appearance) from all plants within each plot were selected for analysis. After analysis of external qualities, fruit Juice was extracted for the chemical analysis. Juice of each fruit was extracted by dividing the fruit into halves and pressing them to pass through a 1 mm metallic sieve, facilitating removal of the fruit coat and the seeds. Data were collected in 7 day intervals.

### • Fruit's external color

Immediately after harvesting, the tomato fruits were washed and wiped to dryness, and color measurements were performed on the opposite sides of the equatorial section of the fruit. Skin color was measured using a Minolta CR 300 Chroma portable colorimeter (Minolta Co., Osaka, Japan) with C illuminant. Fruit chromaticity was expressed in  $L^*$ ,  $a^*$ , and  $b^*$  color space coordinates (CIELAB; Figure 1). The colorimeter was calibrated with a white standard calibration plate ( $Y = 93.9$ ,  $x = 0.3134$ ,  $y = 0.3208$ ) before use.  $L^*$  corresponds to a dark/light scale (0 = black, 100 = white) and represents the relative lightness of colors, being low for dark colors and high for light colors (Lancaster *et al.*, 1997).

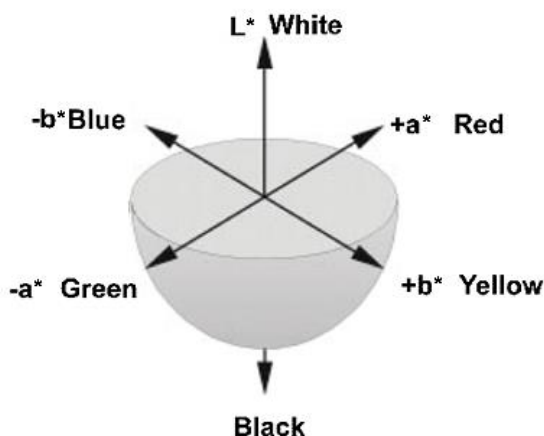
### Fruit shape

Fruit length and fruit width were measured using marked plants each with 4 fruits at physiological maturation time. Fruit shape index was determined as below.

$$\text{Fruitshapeindex} = \frac{\text{Averagefruitlength}}{\text{Diameter}}$$

### • Fruit cracking

After each harvesting, the total number of fruits and the number of fruits showing radial cracks larger and smaller than 2cm were counted. At the same time fruits were classified according to their number of cracks.



**Figure 1.** The CIELAB colour space system.

- **Dry matter content and moisture**

Dry matter content of fruits was analyzed using oven dry method (Kirk and Sawyer, 1990). Petri dishes were weighed and a 10 g of tomato flesh was taken using a grater and cut into smaller pieces in order to facilitate the drying process. Total weight of the fresh sample + Petri dish was taken immediately after placing the sample on the dish in order to avoid loss of water from it. Samples were dried in the oven with an air at 70°C until constant weigh was reached (around 4–6 hours). After the drying, the samples were weighed and noted the total weight of the dry sample + Petri dish (C) was noted. The percentage of dry matter was calculated by using the following formula.

$$\text{Percentage dry matter} = \frac{(C - A) \times 100}{(B - A)}$$

Where,

A = Weight of Petri dish

B = Total weight of fresh sample + Petri dish

C = Total weight of dry sample + Petri dish

- **pH**

Measurements of pH level were conducted on fresh juice samples after shaking vigorously. Bench pH Meter Model 510 was used for the measurements.

- **Total Soluble Solid**

Total soluble solids (TSS) was measured twice on juice from each tomato, using a digital refractometer Atago (ATAGO, Inc. Kirkland, WA, USA) and results were expressed as Brix value. From each fruit, two longitudinal slices (from stem end to calyx-end) were taken. The slice was squeezed longitudinally to get a mixture of juice from all regions. An equal number of drops from the prepared fruit juice was placed onto the refractometer prism plate. The reading on the prism scale was noted to one decimal place. After each test the prism plate was cleaned with water (distilled) and wiped with soft tissue to dry.

- **Titrateable acidity**

Titrateable acid of fruits was analyzed using the method of titration. The tomato fruits were washed, peeled, and cut into small pieces and pulp was prepared by using mixer blinder. A ratio of 2:1 (Pulp: Distilled water; w/v) was utilized in the extraction process. For estimating titrateable acidity, 10 g of extracted juice was thoroughly mixed with 50 ml of deionized distilled water. The mixture was then titrated by adding 0.1 N NaOH until a pH of 8.1 was attained. The volume of the sodium hydroxide, added to the solution, was multiplied by a correction factor of 0.064 to estimate titrateable acidity as percentage of citric acid (AOAC, 1986).

- **Sugar acid ratio**

The sugar/acid ratio contributes towards the fruit's characteristic flavor and is also an indicator of commercial and organoleptic ripeness. The following equation was used to calculate the sugar acid ratio.

$$\text{The sugar acid ratio} = \frac{\text{Brix Value}}{\text{Percentgae of acid}}$$

## **Statistical Analysis**

All extraction runs and analyses were carried out at least in duplicate and in randomized order with the mean values being reported. Analysis of variance (ANOVA) of the results was performed using General Linear Model procedure of SPSS (Software Version 19). Multiple comparison of means was carried out by LSD (Least Significant Difference) test at  $P = 0.05$  and  $P = 0.01$ .

## **Results and Discussion**

According to the growth and yield parameters such as plant height, fresh weight, number of fruit per plant and fruit yield of this study, there was a significant effect of individual stress of water and temperature and in combination (Gunawardena and De Silva, 2015). Therefore, the results of the Quality parameters are discussed in this paper. Ripening rate was inversely related to temperature and water stresses (Sanders *et al*, 1989). Tomato grown in ambient temperature reached fully ripened stage (3 Days after light-red ripeness stage) around 10-11 days. Fruits in the Tomato plants subjected to temperature and water stresses reached full red-ripeness stage about 2 day earlier than control of ambient temperature with no stress condition. There was no significant difference in time required to reach full-ripe stage between treatments. This observation means that the impact of stress condition on the tomato can promote fruit ripening. Temperature and water stresses can enhance ethylene production and it can affect the ripening of tomato, since ethylene is a major hormone coordinating ripening processes in fruits and vegetables.

Quality parameters like high soluble solid and sugar content, pH and fruit colour underline quality of yield. According to previous experience (Stevens and Rudich 1978) soil moisture content influenced some chemical and biological parameters of Tomato. Non water stress condition especially at the end of the growing cycle may lead to a significant reduction of solid soluble and sugar content and acidity. Also individual water stress did not influence fruit colour and pH significantly (Moore *et al*, 1958). This trial emphasized the different responses of individual water stress, individual temperature stress as well as combination stress condition.

## Temperature and water stress on fruit quality parameters

### • Fruit colour

The statistical analysis showed that the average values for  $L^*$  ( $P < 0.05$ ) and  $a^*$  ( $P < 0.05$ ) color parameters were significantly affected by temperature stress, but did not significantly affect water stress and interaction between them (Table 1). When averaged over growing location, the lightness factor  $L^*$  of no water stress in ambient condition was significantly higher and the  $A^*$  values were significantly lower when compared to the fruits growing under stress conditions.

**Table 1.** Fruit colour parameters

Treatments	L	A	B
Ambient tem. No water stress	44.7 $\pm$ 0.5a	26.6 $\pm$ 0.6a	29.5 $\pm$ 0.7 a
Ambient tem. 50% water stress	44.8 $\pm$ 0.5 a	26.7 $\pm$ 0.6 a	28.8 $\pm$ 0.6 a
32°C maximum tem. No water stress	43.7 $\pm$ 0.65ab	24.42 $\pm$ 0.2a b	27.9 $\pm$ 1.1b
32°C maximum tem. 50% water stress	46.3 $\pm$ 0.87a	25.54 $\pm$ 0.12 a	26.8 $\pm$ 1.7a b
34°C maximum tem. No Water stress	41.6 $\pm$ 0.45b	23.51 $\pm$ 0.16 b	23.6 $\pm$ 2.1b
34 °C maximum tem. 50% Water stress	41.4 $\pm$ 0.67b	22.64 $\pm$ 0.19 b	22.5 $\pm$ 1.9 b

Different letters indicate significant at the  $0.01 < P \leq 0.05$  probability level.

### • Fruit shape

Fruit shape is one of the most important physical properties and quality parameters of all agricultural produce. Shape of the tomato

fruits witnessed significant variation with soil moisture condition (Table 2). Fruits of the no water stress treatments were more round in shape than those of imposed water stressed fruits. The lowest shape index (fruit length/diameter ratio) was observed in no water stress treatments. It means that no water stressed plants were able to produce more round shape fruits, whereas plants under temperature and water stress condition produced oval shaped fruits.

**Table 2.** Shape index of fruits

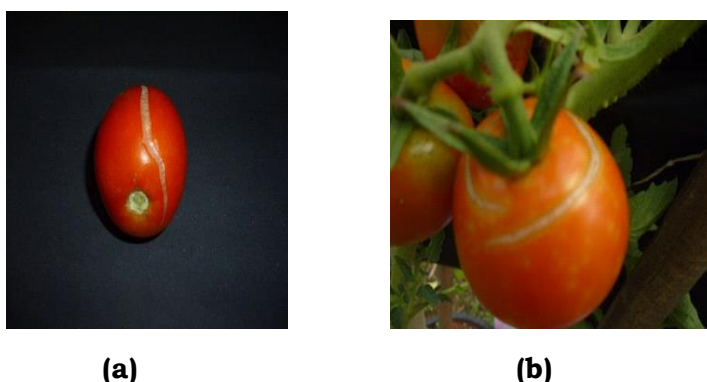
<b>Treatments</b>	<b>Shape index</b>
Ambient tem. No water stress	1.01 ± 0.5 <b>a</b>
Ambient tem. 50% water stress	1.18 ± 0.5 <b>b</b>
32°C maximum tem. No water stress	1.07±0.65 <b>a</b>
32°C maximum tem. 50% water stress	1.19 ±0.87 <b>b</b>
34°C maximum tem. No Water stress	1.08 ±0.45 <b>a</b>
34°C maximum tem. 50% Water stress	1.24±0.67 <b>b</b>

Different letters indicates significant at the  $0.01 < P \leq 0.05$  probability level

- **Fruit cracking**

Fruit cracking in Tomatoes like fleshy fruits can cause serious economic losses. Cracks reduce marketability and provide entry for insects and fungi, causing significant income loss in the fresh market and processing Tomato industries. There are many types of fruit cracking: longitudinal or burst cracking; ring or concentric cracking, crazing or rusting; lenticular cracking; and core failure (Figure 2). In this study, concentric fruit cracks were observed in all treatments except in no water stress condition under ambient environment. Total cracks level was 46% significantly higher ( $p=$

0.05) in 34°C maximum temperature treatments for both water stress and no water stress conditions. Under the green house condition, inside temperature goes beyond 25°C in many occasions. That may be lead to the diurnal stress for the plants growing in the green house. High temperatures in general and sudden high temperatures in mid afternoon in particular, caused red ripe tomato fruit to crack in the maximum 34°C poly tunnel. Raising fruit temperature dramatically increased the pressure exerted by the pulp on the skin and at the same time decreased skin stiffness and strength, increasing the incidence of splitting (Marr and Jirak 1990).



**Figure 2.** (a) Longitudinal and (b) concentric cracks

- **Fruit moisture content**

There were significant reductions in dry matter content at individual water stress compared to the other treatments. Individual water stress treatment had a highly significant ( $p=0.01$ ) negative impact on fruit moisture content (Table 3). Similar individual temperature stress also leads to the reduction of the fruit moisture content but this is not statistically significant. Interaction effects of both stresses severely reduce the fruit moisture content and was significant at the 0.01 probability level.



**Table 3.** Analysis of variance of temperature and water stress on qualitative parameters

Source of variations	df	MS			
		Moisture %	Soluble Solid (°Brix)	pH	Titration Acidity %
Main plot trt (WS)	1	2346.125**	57.537**	0.261**	1.194*
Sub plot trt (TS)	2	16.625	8.681**	0.094**	1.249*
WS*TS	2	37.625**	1.017*	0.24	0.428
Error	12	5.208	0.202	0.08	399

\* indicates significant at the  $0.01 < P \leq 0.05$  probability level; and \*\* indicates significant at the  $\leq 0.01$  probability level

### • Soluble solids content (SSC)

SSC of tested tomato ranged from 4.5 to 12.07 °Brix and 34°C maximum temperature level combined with water stress showed a significant effect ( $p > 0.05$ ) on the soluble solids (°Brix) of tomato fruit with both water stress and no water stress treatment conditions. Both individual stresses had a highly significant ( $P = 0.01$ ) impact on the soluble solid content of the fruit. Moore *et al.* (1958) observed that low water stress resulted in maximum yield of tomato raw product, best viscosity and low soluble solids. In this study, high water stress caused lower yield, highest soluble solids, and poorer viscosity. Ambient temperature treatment yielded good marketable production with less soluble solids than high temperature treatments. This is attributed to the restricted water uptake into the fruit under stress, lower percentage of water in the fruit, and consequently higher solute concentration.

### • pH

In terms of pH (Table 3) no clear pattern emerged, except that no stress fruits tended to have higher pH and fruit with stresses showed lower pH. According to that, individual water stress and high temperature effect had a highly significant effect ( $P = 0.01$ ) on pH of fruits in this study (Table 3). Similarly, studies of the effect of individual water stress on tomato fruit pH have been inconsistent. For example Giardini *et al.*, (1988) found a decrease in fruit pH under stress, while Sanders *et al.*, (1989) found the opposite and

Alvino *et al.*, (1988) found no effect. As the overall flavor intensity of tomato fruits are highly related to pH, acid level and soluble solids content, high sugars and high acids in the proper balance promote the desired flavor.

- **Total titrable acidity**

Total titratable acidity percentage of tomato at full-red ripeness stage ranged from 0.38 to 0.64 among the six treatments. Fruit had the different acidity levels depending on the individual stress effect and interaction effects of the stresses. Fruit treated of higher temperature with water stress had the highest TTA (0.64) and tomato treated at ambient temperature with no water stress had the lowest TTA (0.38 to 0.39). According to the analysis of variance, both individual stresses show significant influence of the acidity development at 0.05 probability level.

- **Sugar acid ratio**

The sugar/acid ratio was calculated on the basis percentage of each individual compound. According to the results of (Table 4) sugars as well as acid content were improved with stimulated stress. Therefore, highest sugar acid ration (20) was observed with 34°C maximum temperature with no water stress condition.

Sugar/acid ratio was calculated to estimate tomato flavour. Low acid content and high sugar content improve fruit quality (Stewart *et al.*, 1977). The metabolism of cellular contents, important for the taste of fruit (for ex. sugars, organic acids, polysaccharides, pigments and aromatic components) changes significantly during the development of the fruits. Therefore, the care for the quality of fruit and yield by metabolic control of these substances during the growth period and during the development of fruits is of special importance.

**Table 4.** Sugar acid ratio

<b>Treatments</b>	<b>Sugar (°Brix)</b>	<b>Acid %</b>	<b>Sugar/acid ratio</b>
Ambient tem. No water stress	4.7±0.69	0.38±0.156	12.36±1.5b
Ambient tem. 50% water stress	5.6±1.07	0.39±0.167	14.35±2.1b
32°C maximum tem. No water stress	6.7±0.65	0.42±0.203	15.95±1.1b
32°C maximum tem. 50% water stress	8.5±0.87	0.54±0.127	15.7±1.7b
34 °C maximum tem. No Water stress	10.2±0.45	0.51±0.163	20±2.1a
34 °C maximum tem. 50% Water stress	12.4±0.67	0.64±0.192	19.375±1.9a

Different letters indicates significant at the  $0.01 < P \leq 0.05$  probability Level.

#### • Diseases

During the first and third seasons tomato plants growing in the poly tunnel were attacked by the Mealy bug which spread very quickly for a few rows of the plants in high temperature poly tunnel (Figure 3). Mealy bugs caused a range of damage symptoms to tomato crops, adults and nymphs fed on the leaves and stems causing necrotic areas and reduced plant vigour. The pest also excreted excess sap (honeydew) on which black sooty moulds grew, which led to the reduction of fruit quality. Researchers have shown that temperature is probably the single most important environmental factor influencing insect behaviour, distribution, development, survival, and reproduction and believe that the effect of temperature on insects largely overwhelms the effects of other environmental

factors (Bale *et al.*, 2002). In general, it is a reasonable assumption that many insect pests have the potential to become more damaging as a result of high temperature or expected climate change. With global warming especially during the dry months, the growth of pests will accelerate, possibly leading to higher population growth. It has been estimated that with a 2°C temperature increase, insects might experience one to five additional life cycles per season (Adil *et al.*, 2003).



**Figure 3.** Mealy bug attach in Tomato

## Conclusions and Recommendations

According to the results, the fruit colour is not in favourable marketable condition when the plants are exposed to temperature and water stress. The fruit shape was round in no water stress conditions and the stress conditions produced an oblong shape with a tip at the bottom. High market value is picked by round fruits than the oblong fruits. Temperature stress made the fruits crack and have low moisture content which led to disease attacks and low marketable value for such fruits. In this study high water stress caused lower yield, highest soluble solids, and poorer viscosity. With respect to pH, no clear pattern emerged, except that no stress fruits tended to have higher pH and fruit with stresses showed lower pH. Treatments exposed to higher temperature with water stress had the highest TTA (0.64) and the treatments at ambient temperature with no water stress had the lowest TTA (0.38 to 0.39). With regard to sugar acid ratio, highest sugar acid ration (20) was observed with 34°C maximum temperature with no water stress condition. Higher sugar acid ration is a good quality feature for

tomato fruits for salads. Disease out break is heavier in high temperature stress conditions.

Therefore, Tomato variety Rajitha could not be a successful open field crop in the dry zone of Sri Lanka if temperature is increased due to global warming. But tomato could be cultivated under green houses by providing adequate water and required kind of soil temperature and management practices. But it will be an expensive venture if one were to calculate the energy used to maintain the green houses in optimum environmental conditions. This experiment should be repeated for other Tomato varieties as well. However, traditional tomato varieties in fact, like Goraka Thakkali may perform better in global warming situations. Producing varieties which perform better under high temperature and water stress may be better than modifying the environment.

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## **Employability of Graduates of Public and Private Management Education Institutes: A Case Study of Two Institutes in Sri Lanka**

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### **Abstract**

The rationale for carrying out this research project lies in the findings of a survey regarding the mismatch between the qualifications and the demand for employment in the job market in Sri Lanka. This study aims to identify the degree of employability of graduates in the public and private sector higher education institutes which offer Management Degree programmes. A combination of quantitative and qualitative methods has been applied to elicit data. Primary data was collected through a questionnaire survey and interviews with 121 selected graduates who had graduated from two selected education institutes to extract views and experiences of graduates who use Facebook and those who use Google+ sites by applying the 'Snowball sampling' method of sampling. The findings suggest that both institutes have paid attention in developing employability skills in their students, supported developing enterprise skills and interpersonal skills which were seen inadequate to fulfil the requirements of the job market.

**Keywords:** Employability, public and private sector higher education, management stream.

### **Introduction**

The demand of higher education has increased considerably and about 12,000 students go abroad each year to pursue higher education as a result of lack of placements in the state universities, (ICEF Monitor 2013). Although, approximately 300,000 students sit for the General Certificate of Examination (Advanced Level), only 27,600 received admissions in universities (UGC 2016). This is not a trend that favours the economic development of Sri Lanka because

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this expenditure does not justify the benefits of educating students who go abroad (Nanayakkara 2010). Therefore, the government has invited the private sector to invest in education; about 100,000 seek further studies annually through the private sector education system and the state does not have the required funding to support this expansion (Dissanayake 2014). However, it is questionable whether these private institutes are adequately equipped to meet the expected quality standards of the country. Further, public universities are frequented with strikes, agitations, clashes and blood-shed and regular closing of faculties and campuses (Nanayakkara 2010) and these educational institutes are often criticized for not accommodating the volume and variety of students' demands, high unit costs arising from unproductive overheads, inflexible curricula and teaching methods, and the lack of research output (Vidanapathirana, 2000).

All the higher education providers in the private sector have established affiliations with different foreign universities and they follow their own quality assurance systems and standards. However, it is necessary to emphasise that there is no state body to supervise the private higher education institutes in Sri Lanka. Because of the necessity to fulfil the rapid demand for high quality higher education, both types of institutes are needed to upgrade the standards of creating employable graduates. Therefore, this study focuses on analysing the employability of graduates in public and private higher education institutes which offer Management Degree programmes.

## **Research Problem**

The state universities in Sri Lanka are operated under the regulations of University Grants Commission (UGC). Therefore, these universities have to follow academic quality standards designed by the UGC and all academic work must be aligned to these standards. The private higher education institutes are affiliated universities of foreign countries. Therefore, these institutes basically follow the academic quality standards given by the mother universities. Many of these affiliated universities are from United Kingdom or Australia. Thus, the education provided by these universities can be different as a result of the quality and nature as maintained by the source university. It is surprising that there is no government authority to monitor the practises of private higher education in Sri Lanka. However, both sectors produce graduates and it is important to study the level of employability of these graduates as they come from two different environments. The study on the employability of both

graduates might support both sectors to identify strengths and weaknesses of the education they provide.

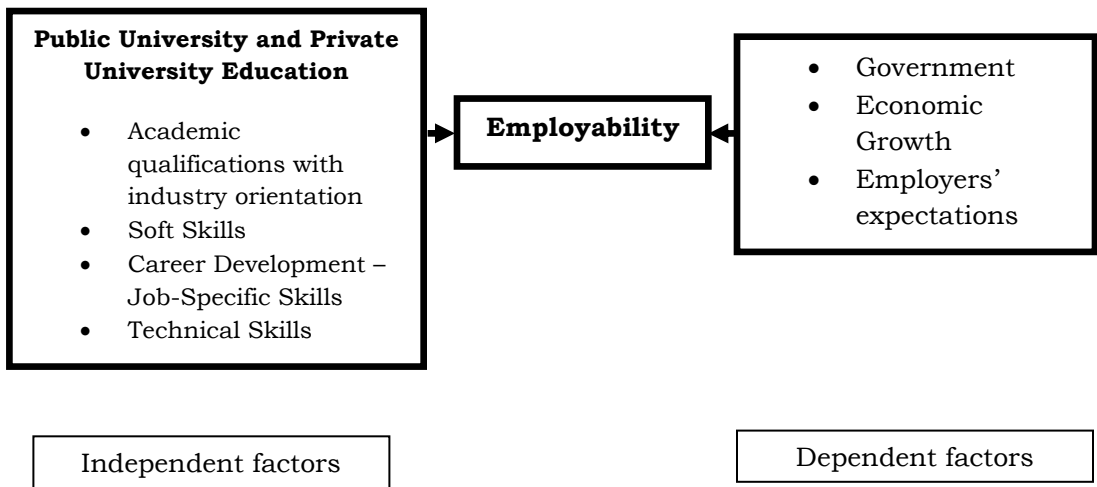
## **Methods**

The selection of the public and private institutes was based on convenience sampling by considering the availability of time and finance. The data was gathered through a survey conducted, based on the snowball sampling method where questionnaires were distributed using Facebook and google+ to graduates of selected institutes. Updated data bases were not available in these two institutes and it led to the selection of snowball sampling to collect participants. Further, online interviews were conducted via Skype to study employment transition, promotions and challenges after graduation. A total of 64 graduates from the public institute and 57 graduates from the private institute participated in this study. The response rate turned out to be 99%. All graduates possessed business management degrees with specializations in finance, accounting, marketing and human resource management. All of them had passed out between 2008 and 2010. They possessed more than four years of working experience when the data was gathered. The questionnaire method was identified as a convenient method for data gathering. In order to identify qualitative factors related to the employability; the researcher conducted interviews with selected graduates. Employability has the influence of dependant variables such as updated theoretical knowledge, soft skills, job specific skills, technical skills and independent variables such as government actions and policies, income and social status, economic growth of the country, and employers' expectations and attitudes of graduates.

## **Conceptual Framework**

The higher education involves factors such as academic knowledge, interpersonal skills development, and exposure to extracurricular activities, economic growth, labour efficiency, job demand, legal framework and political influences. Therefore, these factors can be categorized as dependant and independent factors according to their content and nature of influence. This is illustrated in Figure 01. Offers and services from universities can be dependant and external factors like the government decisions, economic growth, social level and employers' expectations are independent factors in university activities. The efficiency in higher education depends on all of these factors, along with the availability and utilization of finances. The economic growth can be expected to rise through the development of the higher education system of a country. At the same time, there is a positive connection between the skilled labour market and

economic growth (Chandrasiri, 2008). Therefore, the aforementioned foundation must be strong in delivering and developing skills. However, to support the development of higher education in public and private sector requires identifying the common factors affecting the development of the university system. This will support the delivery of balanced mix of academic discipline and practical skills in both public and private sector higher education in Sri Lanka.



**Figure 1.** Conceptual Framework

## Literature review

### Theoretical aspects of employability

Many authors have described employability as the personal aptitude to carry out work. This definition mainly focused on the actual employability of people. Feyter *et.al* (2001) defined employability as “The number of tasks a worker can be assigned to or the amount of assistance needed in the job”. Peck and Theodore (2000) provided a definition to the Employability as ‘all individual factors that influence the future positioning in a given segment of the labour market’. Employability has economic and social consequences on macro- and micro level as the government is required to allocate a sufficient proposition of finance to education and creating employment. In this case, the demand would be created more towards white collar jobs and there will be less demand for blue collar jobs. This will develop a gap in the fulfilment of blue collar job markets. Thus, the authorities have a responsibility in balancing both sides on the development of employability. In this, education

has a responsibility to supply and fulfil the requirements of employability.

Basically, employability is reflected on three theoretical perspectives, namely the Human Capital Theory, Actor Theory and Career Anchor Theory. The knowledge and skills are in great part of the product of investment and, combined with other human investments, predominantly account for the productive superiority of the technically advanced countries (Schultz, 1961). The actor theory implies that the individual and the collective actors are predetermined re-producers of the socially constructed environment. This approach presumes that neither economy as a driving force, institutional norm systems, nor political power structures, define the identity of the individuals, but these forces exert an important influence on the individuals' reflexive and subjective ways of creating their identity (Silverman, 1970). Eight themes in the career anchor such as functional competence, general managerial competence, independence, security, and entrepreneurial creativity, sense of service, pure challenge and lifestyle influence in an individual capability (Schein 1978). The human capital theory, actor theory and career anchor theory argue on education's change of an individual and its preparation of him/her with skills required for the job market. But social, economic and political conditions should provide the foundation in order to convert education into an investment. The Signalling theory argues that the investment in education requires the provision of sufficient return through employment.

### **Importance of academic and practical knowledge in employability**

Education is a major measure of development of a country. Also it reflects the wealth and prosperity of a country. The main objective of university education is to produce graduates with soft and hard skills for different careers expecting them to be in the process of growth in the country. Universities facilitate the production of intellectual needs of a community as regards both academic knowledge and professional training (Ariyawansa, 2008). Higher levels of education becoming more important than lower levels of education, supports the notion that economic activities are becoming more knowledge intensive over time, so that the return to knowledge-based skills is rising (Aturupane, 2012). Employability focuses on a 'rational' approach as there is a range of factors that mediate employment such as, type of higher education institute, mode of study, student location and mobility, subject of study, previous work experience, age, ethnicity, gender and social class

(Harvey, 2001). Employability can be defined as the propensity of students to obtain a job. However, most explicit and implicit definitions elaborate this core notion in diverse ways:

1. Job type: it implies getting a graduate-level job. They may be referred to as 'fulfilling work', or as a job that 'requires graduate skills and abilities' or as a 'career-oriented' job.
2. Timing: employability signaled by getting a job within a specified time after graduating. Attributes of recruitment: does employability signify an ability to demonstrate desired attributes at the point of recruitment?
3. Further learning: one view of employability holds that 'the degree is not the end of learning' and values graduates who are ready for further development, while in other places more weight on achievement at graduation, in addition to recognizing the importance of 'willingness to learn and continue learning'.
4. Employability skills: understood as the possession of basic 'core-skills', or an extended set of generic attributes, or attributes that a type of employer expects from an employee. (discipline-linked, sector-related, company-type) specifies (Flanders, 1995).

Effective employability is a collection of sufficient improvement in knowledge, the field of the subject, relevant experience and the development of positive attitudes and disciplines. These should be injected to individuals by the education institutes.

### **Economic growth and employability**

The Higher education sector is in a position to supply more skilled labour and thereby promote economic growth (Chandrasiri, 2008). A Collaborative approach to higher education and an efficient labour market will lead a country to economic growth. In reality, it can be regarded as a high level or a specialised form of human capital contributes to the economic growth significantly. It is rightly regarded as the 'engine of development in the new world economy' (Castells 1994:15).

### **Social aspects of employability**

Students entering a university may be immature in experience; they are exposed to a lot of freedom and independence without being prepared for the responsibility. This is coupled with a very brief orientation for only one week (sometimes, there is no orientation in private colleges) which in reality is missed by many; consequently,

for many students it takes time to understand the system, especially those from rural schools who are coming to the city for the first time (Bunoti, 2011). The higher education environment should facilitate a proper orientation for students. In the meantime, they should pay attention to the preparation of their students for the demands of the future job market. Therefore, higher education institutes must work in collaboration with the respective industries.

### **Role of higher education institutes**

People are unemployed because of the unemployment mismatch. And there are four main parties who are involved in this process namely, employers, candidates (graduates), state (government) and institutions (university). Most graduates do not have the required competencies, knowledge, skills and experience. Employers are the second party and in their view, graduates fail to fulfil requirements and core competencies. The third party is the educational institute and this system is criticized for not accommodating the volume and variety of students' demands, the high unit cost arising from unproductive overheads, inflexible curricula and teaching methods, and the lack of research output. The fourth party is the government which should also be involved in finding a solution to the problem (Vidanapathirana, 2000). The objectives of university education directly expect a "leading role from graduates" in different scales for the country's development. Therefore, for development, countries highly rely on their valuable human resources, particularly the essence of fresh intellectuals who are known as "university graduates". Hence, it can be argued that one of the universities' main obligations is to produce talented and competent graduates suitable for the development process of the country (Ariyawansa, 2008). Although there are a few established private higher education institutes, they are not labelled as 'universities' and there is little evidence that the education provided by them meets adequate standards.

### **Employers' perspectives**

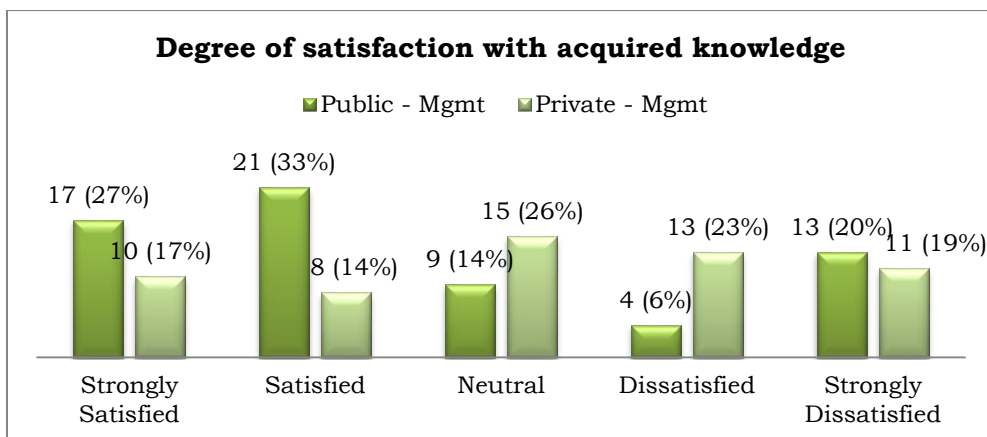
Employers reported that work related experience is an important consideration in recruitment (Weligamage & Siengthai, 2003). Sri Lankan Universities have already taken action on this issue and most of the study programmes have included internship component into their curricula. This programme is running successfully and all stakeholders involved in this process are being benefitted. However, Sri Lanka further requires the development of programmes such as enterprise training, leadership development, career development and interpersonal skill development (Weligamage, 2009). The purpose of

having career guidance services was to improve the links between universities and the industry, and thereby enhance the employability of university graduates (Chandrasiri, 2008).

One of the responsibilities of public and private higher education providers is to produce employable graduates with the intention of balancing the supply of the job market. Various definitions and approaches as discussed under employability of graduates focus on the development of enterprise skills with academic knowledge in relation to the demands of the job market. The required employable skills can vary and are categorized in different job segments. Developing the employment skills of a graduate is a vital need and is recognized all over the world. Therefore, the university system plays an important role in producing suitable and employable graduates to meet the requirements in the economy. There can be a system to update and upgrade degree programmes according to the trends in global higher education and the emerging requirements of the job markets. Universities are places of developing new theories and new knowledge through research and development. Therefore, universities must recognize emerging trends in employment and adjusting their degree programmes, accordingly.

## Results and Findings

The analysis was based on empirical evidence which focuses on a total of 64 graduates from a public institute and 57 graduates from a private institute.



**Figure 2.** Data distribution showing degree of satisfaction with the acquired knowledge

Majority of graduates stated that they were satisfied with the knowledge acquired from the public universities, while dissatisfaction has been shown by a relatively large part of graduates from the private institutes (Figure 2). In addition, 1/5<sup>th</sup> of public university graduates were strongly dissatisfied with the inadequacy of knowledge imparted.

**Table 1.** Analysis on the theoretical knowledge provided by the university

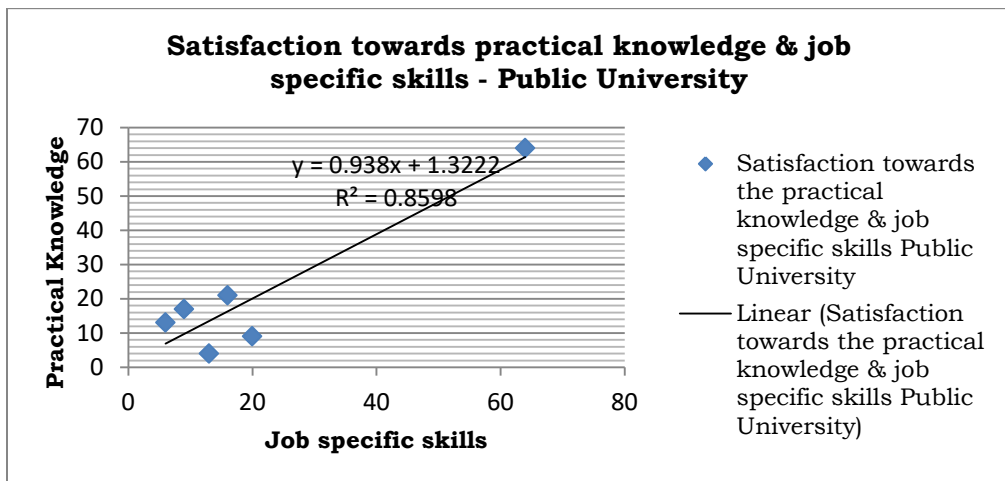
	Satisfaction with the acquired knowledge		Use of the acquired knowledge, in employment		Satisfaction with the gained knowledge and job specific skills		Employment and its relevance to the degree	
	Public Mgmt	Private Mgmt	Public Mgmt	Private Mgmt	Public Mgmt	Private Mgmt	Public Mgmt	Private Mgmt
<b>Mean</b>	12.8	11.4	32	28.5	12.8	11.4	32	28.5
<b>Standard error</b>	2.9	1.2	14	2.5	2.4	3	19	13.5
<b>Median</b>	13	11	32	28.5	13	10	32	28.5
<b>Mode</b>	Satisfied	Neutral	Yes	Yes	Neutral	Dissatisfied	Yes	Yes
<b>Standard deviation</b>	6.6	2.7	19.7	3.5	5.5	6.7	26.8	19
<b>Sample variance</b>	44.2	7.3	392	12.5	30.7	45.3	722	365
<b>Range</b>	17	7	28	5	14	17	38	27

Most of the graduates were not satisfied with the job specific skills provided by the institutes (Table 1). Based on the mean value, over 50% of graduates from both institutes agreed that the acquired knowledge had supported them in securing employment (Table 1). Majority of graduates are employed in fields which are related to their degree specialization. This indicates that graduates have considered the specialized field in applying and selecting employments.



**Table 2.** Data distribution of challenges faced in the first job

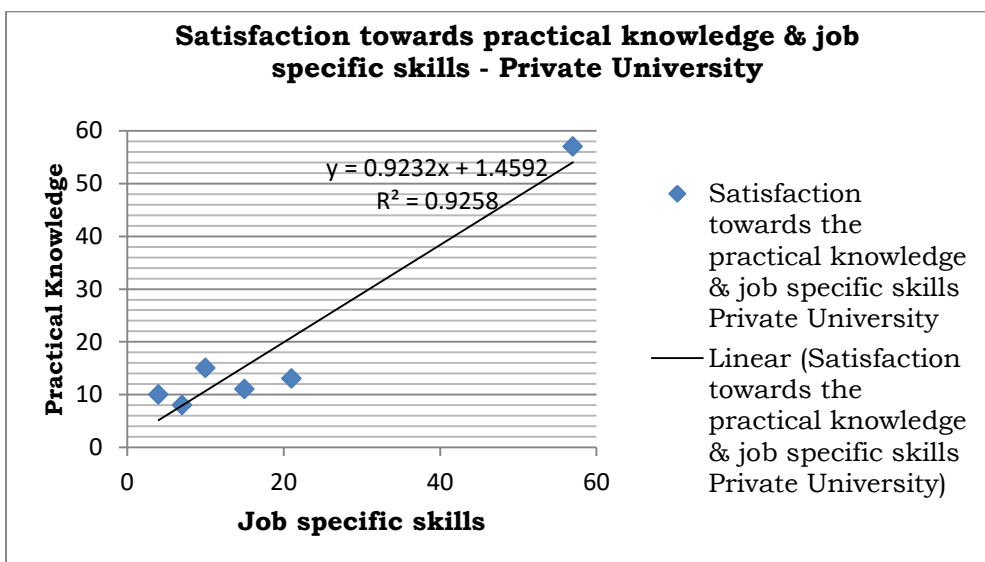
Challenges faced in the first job	Response			
	Public - Mgmt		Private - Mgmt	
English Language	50	47%	9	10%
Computer literacy	12	11%	10	12%
Knowledge	11	10%	23	27%
Practical skills	28	26%	25	29%
General knowledge application in the job	5	5%	16	19%
Any other	1	1	3	3%
Total	107	100 %	86	100%

**Figure 3.** Satisfaction towards practical knowledge & job specific skills - Public University: 64 participants

About 35% of public university graduates are employed in the public sector; public sector jobs are perceivably more secure than other jobs. They also provide higher benefits, such as a pension after retirement and require a lower work effort. Sometimes, they also carry more prestige (Rama, 2003). English Language fluency was the main challenge that graduates of the public university faced (Table 02). Graduates of private institutes mentioned that the institute had not provided enough opportunities to develop practical skills such as industrial training and internships.

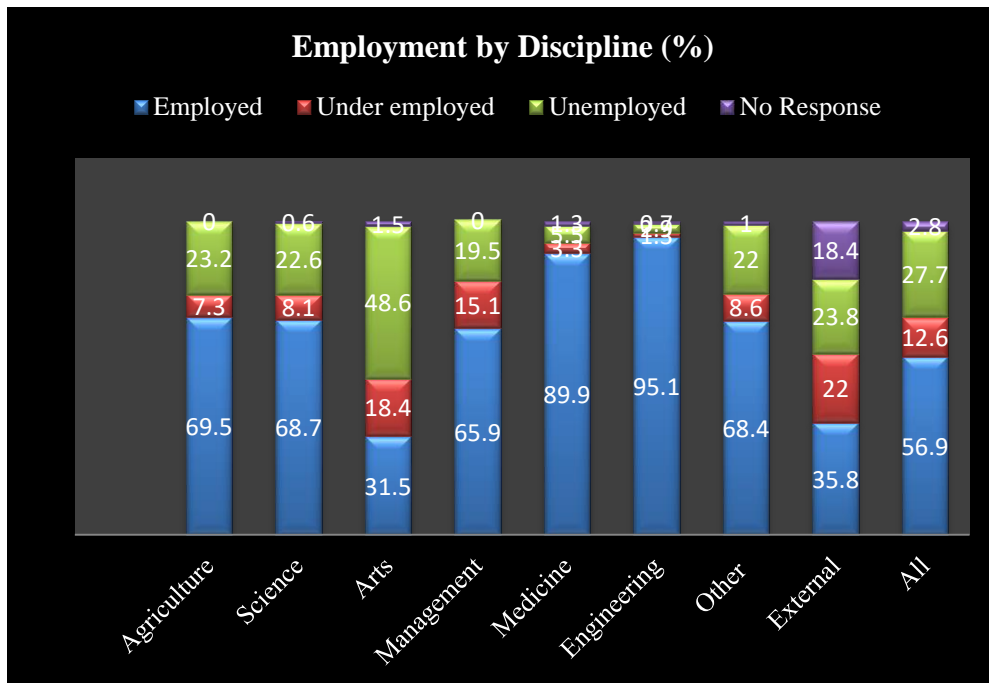
According to Figure 03, there is a positive correlation between the satisfactions of acquired knowledge and the practical skills provided by the Management Degree programme of the Public University. It could be said that satisfaction of acquired knowledge is positively caused by the increase in providing practical skills. Thus, it can be concluded that the impact of higher education must be present in both theoretical and practical knowledge development domains. In other words, these two variables are closely interrelated and an increase in one will make a considerable change in the other. Therefore, these two individual variables require equal attention in order to produce employable graduates.

According to Figure 04, there is a positive correlation between satisfaction gained from knowledge on practical skills provided by the Management Degree programme of the Private Institute. It could be said that satisfaction is positively caused by the extent of practical skills in private education. It can be identified that the satisfaction in both variables is caused by the increase in practical skills. As a result, it can be concluded that the private education considers developing the students' academic knowledge with the job specific skills. Therefore, these two individual variables require simultaneous development as well as equal attention in order to produce employable graduates.



**Figure 4.** Satisfaction towards practical knowledge & job specific skills - Private University: 37 participants

## Discussion



**Figure 5.** Employment by Discipline - Graduate Employment : Ministry of Higher Education - 2012

The Ministry of Higher Education has been surveying the employability of graduates annually until 2013. This survey produces data on employability of recent graduates by the discipline and the university. Figure 05 shows the employability of graduates by the relevant discipline; management graduates have an employability rate of 66% in all the state universities. The data was collected on the day of convocation, which may be 6 – 12 after the completion of their degrees. Therefore, it also reflects the waiting time to receive a job.

According to Table 03, there were 20 graduates who participated in the interview from the Public University and 12 of them were female graduates. Currently, 11 out of the 20 interviewees are working in public sector organizations, while 8 females worked in that sector. However, there were no graduates from the Private Institute who work for the public sector. There are 7 graduates who work in the private sector and a further 3 of them run their own companies.

**Table 3.** Background of interviewees (M=Male, F=Female)

	No of graduates	M	F	<b>Employment</b>							
				Private jobs		Public jobs		Self employed		Unemployed	
				F	M	F	M	F	M	F	M
Public Uni	20	8	12	4	4	8	3	-	1	-	-
Private Uni	10	5	5	4	3	-	-	1	2	-	-
Total	30	13	17	15		11		4		-	

**Table 4.** Waiting time to get employment

	Internship converted to permanent employment	No waiting	One month	02-03 months	4-6 months
Public Uni	9	5	2	3	1
Private Uni	-	5	3	2	-

Internship is compulsory in the curriculum of the Management stream in the Public University. Therefore, all graduates had gone through an internship programme. Some of them had converted the same internship to permanent employment after completing the required probation period (Table 4). Others received employment while they were on internship. One of the interviewees stated that she had to wait for three months after completing her studies to secure employment. Four interviewees out of the 30 are working for their own companies. The private university graduates were not required to stay long to receive jobs as they obtain jobs through personal contacts.

**Table 5.** Data analysis on self-employment (**I** = Interviewee)

Graduate proprietors	<b>I</b>	Source of investment	Time taken to start the business	The time of joining	Size of the business
Public – Mgmt Uni	A	Bank loan	Expanded the existing business	During university studies	Medium (business has developed from a micro level to medium)
Private – Mgmt Uni	B	Parents' money	Less than a month	After completion of the degree	Medium (started as a sister company of the parents' business)
	C	Parents' money	Expanded the parents' business	After completion of the degree	Small
	D	Parents' money and Bank loan	Expanded the parents' business	After completion of the degree	Medium (started as a sister company of the parents' business)

As Table 5 shows, three interviewees of the Private Institute have started their own businesses just after their graduation receiving investment from their parents/family members/only one interviewee of the Public University is running his own business which was financed through a bank loan. He had started this business as a micro enterprise and has now developed it to a small/medium scale enterprise.

### **Incentives for Employment – Public sector and private sector companies**

The sample consists mainly of those who graduated in 2008 and had received a chance to get public sector jobs in the late 2009–2010 years. During the interview, it was found that there were incentives in both sectors which graduates looked for.

**Table 6.** Ranking of incentives in working in the private/public sector


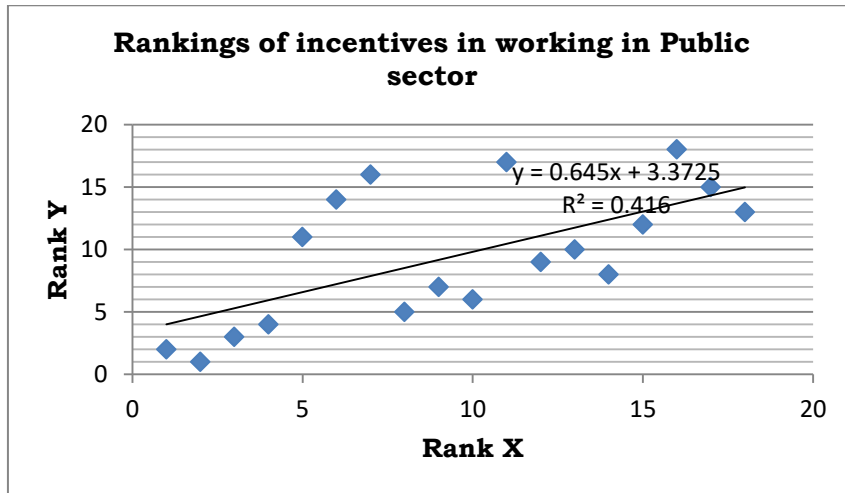
Private Sector workers	Public Sector workers	
<ol style="list-style-type: none"> <li>1. Salary</li> <li>2. Quick Career growth</li> <li>3. Accept qualifications</li> <li>4. Relevance to the field of study</li> <li>5. Family wellbeing</li> <li>6. Further education</li> <li>7. Rewards</li> <li>8. Efficiency</li> <li>9. Exposure</li> <li>10. Culture</li> <li>11. Job security</li> <li>12. Transparent recruiting procedure</li> <li>13. Accept experience</li> <li>14. Travel distance</li> <li>15. Freedom</li> <li>16. More holidays and other benefits</li> <li>17. Time saving</li> <li>18. Pension scheme</li> </ol>	<ol style="list-style-type: none"> <li>1. Job security</li> <li>2. Family wellbeing</li> <li>3. Pension scheme</li> <li>4. Travel distance</li> <li>5. Time saving</li> <li>6. Salary</li> <li>7. Freedom</li> <li>8. More holidays and other benefits</li> <li>9. Further education</li> <li>10. Accept experience</li> <li>11. Rewards</li> <li>12. Quick Career growth</li> <li>13. Accept qualifications</li> <li>14. Relevant fields available</li> <li>15. Efficiency</li> <li>16. Exposure</li> <li>17. Culture</li> <li>18. Transparent recruiting procedure</li> </ol>	<p>Most important</p>  <p>Least important</p>

Table 6 presents the ranking order for each incentive and it is very clear that two different views have come out in these two types of sectors. Salaries, career growth, qualification requirement, relevance to the field of study and family wellbeing are the top most important incentives of private sector employees. However, job security, pension, family wellbeing, travelling distance, time saving and freedom are the main concerns of public sector employees. One participant from the public university mentioned that he had to shift his employment from the private sector to the public sector as there are many benefits provided for public sector workers including the

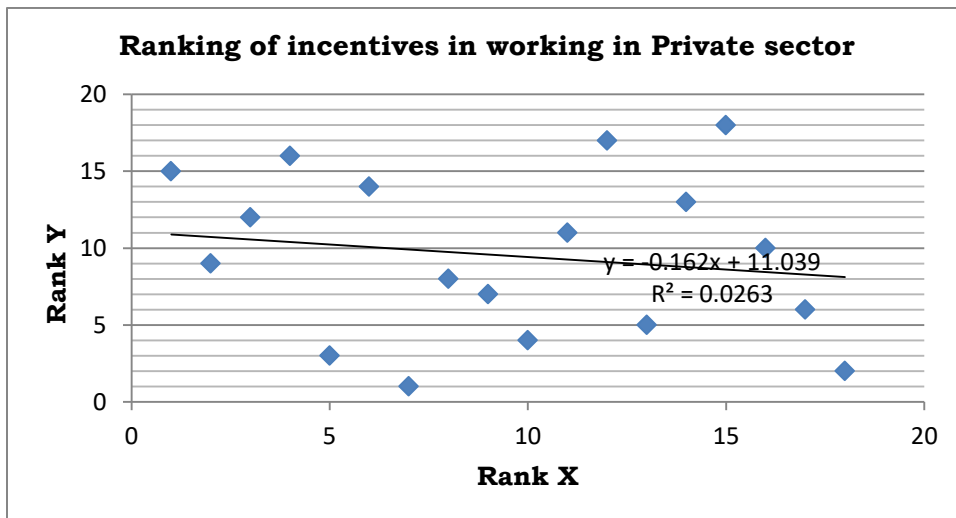
pension. It was also very easy to work close to home rather than be lodged in Colombo away from home.



**Figure 6.** Spearman rank correlation of incentives in working in the public sector – Public University graduates

The figure 6 presents the spearman's rank correlation of the preference of selecting public sector employment. This is a positive correlation based on the incentives listed in the Table 6. The graduates of the public university have more preference of selecting private sector employment.

The results of identifying the preference of working in the private sector are presented by the Figure 7. This indicates a negative correlation with the ranked incentives presented in Table 6. These graduates expect a high salary and quick career growth by working in the private sector. One of the participants from the public university said that although she was entitled to a government offer, she declined as she wanted to continue in the private sector considering the salary package and the relevance of the degree for further education.



**Figure 7.** Spearman rank correlation of incentives in working in the private sector – Public University Graduates

While the majority of graduates stated their satisfaction of acquired knowledge from the Public University, dissatisfaction was stated by a greater number of graduates from the Private Institute. Most of the graduates were not satisfied with the practical and job specific skills provided by both institutes. Many graduates from both institutes, however, agreed that the acquired knowledge had supported them in their employment.

## Conclusion

This study highlights the major factors affecting the employability of graduates of public and private higher education especially in the Management stream. Based on the results of this research relating to two institutes, it was observed that, academic knowledge, soft, practical and technical skill development are the major factors that prepare an undergraduate for future employment. These results also conclude that providing academic knowledge is not sufficient for effective employability of graduates. Findings have shown the dissatisfaction of graduates towards their academic programmes as inadequate in academic and practical skills development. It appears that higher education institutes must have a proper combination of academic knowledge and practical skills development which are expected by employers. As Weligamage and Siengthai mentioned in 2003, the Knowledge, skills, and talent will be crucial factors for growth in the future, while innovation and willingness to change will be driving forces in higher education. Therefore, these institutes have a major responsibility to improve their academic standards.



Graduates are the future leaders of the country and they have to be ready with the modern changes in the industry. There should be a system set up for undergraduates to engage in industrial activities during their time of study and help create relationships and network with industries. Therefore, the nexus between university and corporate entities needs nourishing. The study shows that public university graduates prefer to work for public sector. However, this liking may be used to locate them in their home towns to develop those areas and facilitate them to strengthen opportunities for local businesses. The objectives of university education directly emphasize a “leading role from graduates” in different scales for the country’s development (Ariyawansa, 2012). Public universities have to play change preferences (unclear?) and interests of their students to work for private sector. The findings of this study may have significant influence on planning and strategising higher education in Sri Lanka; it will help both sectors to understand how they need to develop and upgrade themselves in order to produce employable graduates.

### **Implications for Future Research**

This study provides an example where there is some convincing evidence to investigate further the requirement of developing higher education sector of Sri Lanka. The results show the factors affecting the employability of graduates in Management stream based on two private and public institutes. Further research may be justified to investigate the impact of applying these factors in developing the employability skills among both undergraduate programmes. This study highlights only the employability of management graduates; therefore, this can be expanded further to investigate the employability of other streams in higher education. The results of this study can enhance the development of academic standards in both public and private higher education institutes in Sri Lanka.

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## **Role of Silicon on Enhancing Disease Resistance in Tropical Fruits and Vegetables: A Review**

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### **Abstract**

Silicon (Si) has proven to enhance disease resistance in a wide range of tropical fruits and vegetables. It has been used in controlling various diseases: mildews, rots, moulds, wilt, blight, anthracnose and leaf spots. However, the highest number of records was available on reducing diseases of powdery mildews on fruits and vegetables belonging to the family Cucurbitaceae. Silicon-mediated defense responses in plant pathosystems are mainly attributed to the physical resistance, which involves reduced penetrability and/or increased hardness and abrasiveness of plant tissues because of silica deposition. The main mechanism is the chemical resistance, which involves chemical defenses to pathogen attack through the enhanced production of defensive enzymes and the production of antifungal compounds such as phenolic metabolism products, phytoalexins and pathogenesis related proteins. Silicon has been applied as soluble silicates to the substrate or to soilless media at pre-harvest level on reducing disease susceptibility. Post-harvest dips of fresh produce in silicate solutions and use of Si combined with a biocontrol agent are other aspects of silicon application in controlling diseases in fruits and vegetables.

**Keywords:** Silicon application, plant pathogens, defense responses

### **Introduction**

Silicon (Si) is taken up by plants at concentrations similar to the

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essential nutrients. However, persistent chemical fertilization and crop removal from the field tend to the depletion of Si availability for plants. As a result, Si has been identified as a limiting factor for Si-accumulating plants, as well as for the plants grown in soils deficient with Si (Epstein, 1999). The beneficial effects of Si have been observed in a wide variety of plant species including enhanced insect and disease resistance, reduced mineral toxicity, increased photosynthetic activity, superior nutrient imbalance, and enhanced drought and frost tolerance (Ma, 2004). Though silicon has not been recognized as an essential element for plant growth, plants deprived of Si are often weaker structurally and more prone to abnormalities of growth, development and reproduction. Silicon is considered as the only nutrient element which is not detrimental when collected in excess in plants (Ma and Takahashi, 2002).

Silicon is absorbed to plants from the soil solution with concentrations ranging from 0.1 to 0.6 mM as monosilicic acid,  $\text{H}_4\text{SiO}_4$  (Ma and Takahashi, 2002). The Si concentrations vary widely in above ground plant parts, ranging from 0.1 to 10.0% on dry weight basis (Liang *et al.*, 2005). Plant species are considered as Si 'Accumulators' when the concentration of Si of its dry weight is greater than 1%. 'Intermediates' have Si amounts less than 0.1% in their biomass. Plants containing Si concentration below 0.5% of the bio mass are considered as 'Excluders' (Ma and Takahashi, 2002).

Silicon has been found to effectively control many of the diseases found in tropical fruits. However, diseases, such as blue mould and gray mould were reduced in fruits grown in temperate countries.

Silicon has been applied as a form of pre-harvest or post-harvest application, or root or foliar application. The research has also been done on silicon application in combination with yeast or phosphorus acid or hot water treatment. Different sources of silicon i.e. sodium silicate, calcium silicate, calcium silicate, rice hull (raw or partially burnt) have been used as sources for providing Si to the fruits and vegetables.

The following sections describe the disease control by application of silicon in tropical fruits and vegetables. Some records were available on reducing anthracnose disease in tomato and capsicum grown in

Sri Lanka.

## **Silicon and mildew diseases**

### **Powdery mildew**

A noticeable inhibitory effect against powdery mildew has been reported by silicon application in cucurbits. A majority of the alleviative effects studies has been accounted in cucumber powdery mildew caused by *Sphaerotheca fuliginea* (Samuels *et al.*, 1993; Menzies *et al.*, 1991; 1992; Fawe *et al.*, 1998; JungSup *et al.*, 2000; Schuerger and Hammer, 2003; Wei *et al.*, 2004; Liang *et al.*, 2005; QiuJu *et al.*, 2009; Buttaro *et al.*, 2009; Wolff *et al.*, 2012) and by *Sphaerotheca fuliginea* (Liang *et al.*, 2005). Effective suppression of the disease could be observed in some other cucurbits such as melons caused by *S. fuliginea* and/or *Erysiphe cucurbitacearum* (Menzies *et al.*, 1992; Yurong *et al.*, 2005; Guo *et al.*, 2005; Chen *et al.*, 2010). Root applied Si induced the resistance against *Podosphaera xanthii* reducing the disease severity in melon. Supplying silicon in nutrient solutions reduced the severity and incidence of powdery mildew in two varieties of melon, carosello and barattiere (Buttaro *et al.*, 2009). Furthermore, powdery mildew in zucchini squash caused by *E. cichoracearum* and *Podosphaera xanthii* pumpkin caused by *P. xanthii* (Heckman *et al.*, 2003) was lessened by pre-harvest silicon application.

Palmer *et al.* (2006) reported that powdery mildew caused by *Sphaerotheca aphans* in strawberry can effectively be suppressed by foliar application of potassium silicate. Silicon had beneficial effects on strawberry plants and may serve as an alternative to fungicides for controlling powdery mildew when supplied as a foliar spray of potassium and sodium silicate. Kanto *et al.* (2004, 2007) and Wang and Galletta (1996) have recorded similar results about the strawberry- powdery mildew patho-system. However, root application of silicon could not reduce the disease severity in strawberry (Bowen *et al.*, 1992). Similar suppressive effects of Si against *Uncinula necator* were stated by Reynolds *et al.* (1996) and Blach and Grundhofer (1998) in grapes. Foliar applied potassium silicate was found to exhibit inhibitory effects on *Leveillula taurica*,

the powdery mildew causing fungi in tomato (Yanar *et al.*, 2013).

## **Downy mildew**

Foliar application of Si suppressed cucumber downy mildew caused by *Pseudoperonospora cubensis* (Yu and Du, 2009; Yu *et al.*, 2010). Garibaldi *et al.* (2012) discovered that electrical conductivity and potassium silicate together significantly influenced downy mildew (*Bremia lactucae*) incidence and severity on lettuce in hydroponic system. The best results, in terms of disease control, were given by the addition of potassium silicate to the 0.95 g l<sup>-1</sup> NaCl solution.

## **Silicon and rot diseases**

### **Fruit rots**

#### **Alternaria fruit rot**

The synergistic effects of biocontrol yeasts *Cryptococcus laurentii* and *Rhodotorula glutinis* combined with silicon against Alternaria fruit rot (*Alternaria alternata*) have been investigated in jujube fruit (Chinese date: *Zizyphus jujuba*). Combinations of *C. laurentii* and *R. glutinis* with Si were found to be most effective in controlling the diseases caused by *A. alternata* in jujube fruit (Shiping *et al.*, 2005). Post harvest sodium silicate treatments could resist the growth of *A. alternata* in pingguoli pear (Guo *et al.*, 2003).

#### **Other fruit rots**

The susceptibility to pink rot caused by *Trichothecium roseum* was shown to be decreased by postharvest Si application in muskmelon (Li *et al.*, 2012), Chinese cantaloupe (Yurong *et al.*, 2003; Guo *et al.*, 2007) and hami melon (Bi *et al.*, 2006). Yang *et al.* (2010) have revealed synergistic effects of silicon on disease control in apple brown rot (*Monilinia fructicola*). Foliar application of Si was effective in controlling tomato fruit rot caused by *Phytophthora capsici* (Mersha *et al.*, 2012)

### **Root rots**

#### **Pythium root rot**

It was stated that Si is effective in controlling root rot in cucumber



caused by *Pythium ultimum* and *P. aphanidermatum* (Cherif and Belanger, 1992; Chérif *et al.*, 1994a, 1994b). However, Heine *et al.* (2007) revealed that the incidence of root rot in cucumber, tomato and bitter melon caused by *P. aphanidermatum* could not be controlled by Silicon application.

### **Phytophthora root rot**

Silicon was effective in controlling cucumber root rot caused by *Phytophthora melonis* (Mohaghegh *et al.*, 2011). In hydroponic experiments, Khoshgoftarmanesh *et al.* (2012) have demonstrated that Phytophthora root rot (*P. drechsleri*) in cucumber could be alleviated by Si application. Bekker *et al.* (2007) found the efficacy of root application of potassium silicate on controlling the disease (*P. cinnamomi*) in avocado.

### **Fusarium root rot**

Due to the application of Si to tomato seedlings, the disease severity of root rot caused by *Fusarium oxysporum* f.sp.*radicis-lycopersici* was reduced. This inhibitory effect was due to the delaying in onset and initial infection of roots and the movement of the pathogen from roots to stems (Huang *et al.*, 2011). Silicon was also reported to be effective to suppress the disease resulted by *F. solani* in tomato (El-Samman *et al.*, 2000). *Fusarium oxysporum* f.sp.*radicis-cucumerinum*, the causative fungi of cucumber root rot, could be effectively controlled by soil applied Si (Safari *et al.*, 2012). The alleviative role of Si on the disease was also recorded in other cucurbits in fact hamimelon: *F. semitectum*, cantaloupe: *Fusarium spp.* and rock melon: *F. oxysporum* f. *Sp. Melonis* (Bi *et al.*, 2006; Liu *et al.*, 2009; Kumar and McConchie, 2010)

### **Pink rot**

Si application has also been shown to decrease susceptibility to pink rot caused by *Trichothecium roseum* in muskmelon (Li *et al.*, 2012), Chinese cantaloupe (Guo *et al.*, 2007; Yurong *et al.*, 2003) and hami melon (Bi *et al.*, 2006).

## Banana root rot

Using the image analysis program WinRHIZO, Vermeire *et al.* (2011) exhibited that root-rot fungi *Cylindrocladium spathiphylli* infection in banana could be mitigated. The Si amendment also alleviated growth reduction caused by the pathogen.

## Silicon and mould diseases

### Blue mould

Ebrahimi *et al.* (2012) explained that postharvest silicon application was more effective in reducing the lesion diameter of blue mould decay of apples caused by *Penicillium expansum* in combination with the yeast, *Torulaspora delbrueckii* than using Si or *T. delbrueckii* alone. In a consequent study, Ebrahimi *et al.* (2013) discovered the efficacy of controlling the disease triggered by applying Si together with the yeast, *Metschnikowia pulcherrima*. Farahani *et al.* (2012) suggested that the yeast, *Candida membranifaciens* combined with different concentrations of silicon, improved the effectiveness of yeast in controlling the disease in apple. Similar results have been observed by Farahani *et al.* (2013) by dual application of silicon and the yeast, *Pichiaguillier mondii* in apples. Postharvest dips of apples in potassium silicate solution (Moscoso-Ramírez and Palou, 2014) and in Si added hot water (Etebarian *et al.*, 2013) were other means of suppressing the disease. Combinations of the yeast species, *Cryptococcus laurentii* and *Rhodotorula glutinis* along with Si was more successful in controlling blue mould caused by *P. expansum* on jujube fruit (Shiping *et al.*, 2005).

### Green mould

Silicon has been reported to prevent the incidence of green mould caused by *Penicillium digitatum* in a number of citrus fruits (Abraham, 2010; Liu *et al.*, 2010). Mkhize *et al.* (2013) revealed that pre- and post-harvest Si amendments could upsurge the resistance of lemon to *P. digitatum*. Postharvest dips of potassium silicate before inoculation the same pathogen on oranges significantly reduced the severity of green mould (Moscoso-Ramírez and Palou, 2014).

## White mould

In bean, disease incidence and severity of white mould (*Sclerotinia sclerotiorum*) were significantly reduced by 52% and 73%, respectively, via applying Si as calcium silicate together with calcium chloride (PaulaJúnior *et al.*, 2009).

## Gray mould

On increasing the quality of organically grown strawberry, Prokkola and Kivijärvi (2008) found that silicon is effective in controlling gray mould (*Botrytis cinerea*), when applied as a combination with *Trichoderma* spp. in two weeks interval until harvested. Soil application of liquid potassium silicate to cucumber plants notably reduced the incidence of gray mould caused by *B. cinerea* (O'Neil, 1991). In contrast, post-harvest Si application was found to be ineffective for controlling gray mould (*B. cinerea*) in strawberry (Lopes *et al.*, 2014).

## Silicon and wilt disease

### Bacterial wilt

Soil supplied silicon enhanced the resistance in tomato plants against *Ralstonia solanacearum*, the causing agent of bacterial wilt (Ghareeb *et al.*, 2011). Silicon amendments were also reported to reduce the disease incidence in tomato when applied to soil (Dannon and Wydra, 2004; Diogo and Wydra, 2007; Kiirika *et al.*, 2013). However, dual application of silicon and a rhizobacteria strain *Bacillus pumilis* against the disease was not effective as same as application of silicon alone in tomato (Kurabachew and Wydra, 2014).

Recently, it was revealed that Si mediated resistance in tomato against *R. solanacearum* was associated with the changes of soil microorganism amount and soil enzyme activity (Wang *et al.*, 2013). The uptake of Si was significantly increased in the Si-treated tomato plants, where the Si content was higher in the roots than that in the shoots. The results showed that exogenous 2.0 mM Si treatment

reduced the disease index of bacterial wilt by 19.18 % to 52.7 %. Si supply significantly increased soil urease and soil acid phosphatase activity under pathogen-inoculated conditions. After *R. solanacearum* inoculation, Si amendments significantly increased the amount of soil bacteria and actinomycetes and reduced soil fungi/soil bacteria ratio. The results suggested that Si amendment is an effective approach to control *R. solanacearum*, and Si-mediated resistance in tomato against *R. solanacearum* is associated with the changes of soil microorganism amount and soil enzyme activity (Wang *et al.*, 2013). Silicon amendment significantly reduced bacterial wilt incidence of tomato grown in peat substrate (Diogo and Wydra, 2007) and hydroponic culture (Dannon and Wydra, 2004).

### **Fusarium wilt**

Fortunato *et al.* (2012) revealed that supplying Si to banana plants at seedling stage had a great potential in reducing the intensity of Fusarium wilt caused by *Fusarium oxysporum*. The suppressive effect of Si on the disease in cucumber caused by *Fusarium oxysporum* f.sp. *radicis-cucumerinum* was also reported by Safari *et al.* (2012).

### **Silicon and blight**

#### **Phytophthora blight**

In cucumber, root applied liquid potassium silicate notably reduced the incidence of stem blight caused by *Didymella bryoniae* (O'Neil, 1991). Silicon accumulation in roots followed by Si supply could potentially reduce the severity of Phytophthora blight caused by *Phytophthora capsici* while enhancing the plant development in bell pepper (French-Monar *et al.*, 2010) as well as in pepper (Lee *et al.*, 2004). Foliar application of soluble silicon could efficiently control the disease in tomato caused *P. capsici* (Mersha *et al.*, 2012). In addition, silicon nutrition enhanced the resistance to stem blight caused by *Phomopsis asparagi* in two asparagus cultivars, UC157 and Gynlim (Lu *et al.*, 2008).

## Stem blight

Application of liquid potassium silicate through a separate set of drip lines to cucumbers grown on rockwool slabs significantly reduced the incidence of stem blight caused by *Didymella bryoniae*, and appeared to reduce that of those caused by *B. cinerea* (O'Neil, 1991).

## Silicon and anthracnose

Yang *et al.* (2008) have revealed that it could control the occurrence of anthracnose (*Colletotrichum higginsianum*) of flowering Chinese cabbage (*Brassica campestris* L.) on Si application. Injecting soluble silicon into trees prior to harvest significantly decreased the severity and incidence of postharvest anthracnose in avocado while, a combination of soluble silicon and phosphorous acid was not that effective in controlling of anthracnose (Anderson *et al.*, 2005). The disease in avocado could similarly be controlled effectively by postharvest application of soluble silicon (Bosse *et al.*, 2011). The susceptibility to the disease (*C. gloesporioides*) in tomato was mitigated by soil application of sodium silicate (David and Weerahewa, 2012; Weerahewa and David 2015), and application of partially burnt rice hull (Somapala *et al.*, 2015). Root and shoot applied Si was proven to be an effective way of reducing the disease severity caused by *C. gloesporioides* in *Capsicum annuum* L. 'Muria F1' (Jayawardana *et al.*, 2014, 2015). The significant reduction of anthracnose disease was observed in capsicum grown in simplified hydroponics system incorporated with raw rice hull as a supplement of silicon (Jayawardana *et al.*, 2016). Moreover, Si induced the resistance against *Fitopatologia Brasileira* and *C. lindemuthianum* in bean (Moraes *et al.*, 2006; Polanco *et al.*, 2012, 2014).

## Silicon and Leaf spot

Foliar application of potassium silicate, as a source of soluble silicon, decreased angular leaf spot (*Pseudocercospora griseola*) severity on beans at more alkaline pH (Rodrigues *et al.*, 2010).

## **Banana sigatoka**

The effect of silicon uptake on the susceptibility of banana to *Mycosphaerella fijiensis*, the causative pathogen of black sigatoka disease was investigated by Kablan *et al.* (2012). It was revealed that Si supply could alleviate the disease in the plants grown both in hydroponic culture system and in pots filled with compost.

## **Underlying mechanism/s of disease resistance mediated by silicon**

There are mainly two methods by which Si induces the resistance in plants against infections. It is either by the chemical defense owing to the physical defense developed due to Si deposition on plant tissues preventing the pathogen penetration and/or by synthesis of anti-pathogenic compounds. In addition, systemic acquired resistance (SAR) was found to be induced upon silicon application in fruits and vegetables.

## **Mechanical Resistance**

Silicon has been shown to be effective in mitigating biotic stress by means of mechanical resistance in fruits and vegetables in a number of studies. Pre-harvest or post-harvest silicon application had shown a great potential in controlling diseases by inhibiting or delaying the growth and development of the mycelium of the pathogen (Samuels *et al.*, 1993; Bowen *et al.*, 1992; Hu *et al.*, 2008; Yu and Du, 2009; Abraham, 2010) due to silicon deposition at infection sites and hyphae (Reynolds *et al.*, 1996)

Si application strongly inhibited spore germination, germ tube formation and development of appressoria and possibly the penetration of fungi were hindered. It was hypothesized that Si inhibits fungal disease by physically inhibiting fungal penetration peg dispersion of the epidermis (Menzies *et al.*, 1991a, 1991b; Bowen *et al.*, 1992; Yurong *et al.* 2005; Kanto *et al.*, 2007; Liu *et al.*, 2010). Si was translocated laterally through the leaf and surrounded the appressoria of *U. necator* upon foliar application of Si. Plant leaves that were fed with Si via roots showed a similar deposition of Si surrounding the appressoria making a rigid physical barrier for penetration (Bowen *et al.*, 1992).

It has also been found that the trichome bases on the epidermis tend to become silicified (Belanger *et al.*, 1995; Samuels *et al.*, 1993; Chérif *et al.*, 1994a) changing their morphology against infections. Si deposition in leaf hairs suppressed the fungal penetration as a result of increased density and length (Fatema *et al.*, 2011). Penetration peg incursion was found to be constrained by rapid Si deposition at the external openings like stomata of the leaves (Guo *et al.*, 2007). A fast silicification at intercellular spaces, cuticle layer (Kanto *et al.*, 2007) and along the space between the exocarp and mesocarp (Guo *et al.*, 2007) made it more difficult for pathogen penetration and dispersion. Powdery mildew infected leaf cells of silicate treated plants were exhibited to have extensive silica polymerization enhancing the thickness against the fungi in the halo region surrounding the site of fungal penetration (Menzies *et al.*, 1991b). Altered surface morphology of the host cell walls was observed adjacent to the germinating hyphae (Samuels *et al.*, 1993). Deposition of silicon in host cell walls, papillae, around the haustorial neck and in-between the host cell wall and plasma membrane enhanced induced structural defense reactions (Samuels *et al.*, 1994) against *S. fuliginea*.

Changes in the pectic polysaccharide structure, is another aspect of silicon-induced mechanical defense. In particular, arabinan side chains of rhamnogalacturonan I increased in some vessel walls and galactan side chains of rhamnogalacturonan I increased in the xylem parenchyma, increasing the mechanical strength of the host against infection (Diogo and Wydra, 2007). Si application increased the cell wall lignin content which made it hard for dispersion of fungal mycelium (Polanco *et al.*, 2012). Silicon-treated plants increased resistance against infections by forming electron-dense layers along primary and secondary cell walls as well as over pit membranes of xylem vessels (Chérif *et al.*, 1994b) making it harder for fungal permeation and dispersion within the plant body.

## **Biochemical resistance**

Silicon-mediated defense reaction is induced in fruits and vegetables by synthesis of secondary metabolites. Secondary

metabolites influence the interactions between plants and the organisms that inhabit their environment: insects and other animals, microbes and fungi. They are obnoxious, repellent or downright toxic to biotic attackers of plants (Delhaize *et al.*, 1993). Antioxidant enzymes, phenolic compounds, chitinases and phytoalexins are the common secondary metabolites found related to chemical defense in fruits and vegetables.

### **Acquired resistance through antioxidant enzymes**

Several studies showed that lowering disease severity in the Si-treated plants was in line with higher activity of antioxidant defense enzymes in particular, superoxide dismutase, catalase, peroxidase, ascorbate peroxidase, guaiacol peroxidase,  $\beta$ -1, 3-glucanase and glutathione reductase. Plants protect cell and sub cellular systems from the cytotoxic effects of the active oxygen radicals using antioxidant enzymes. Silicon was said to be effective in controlling pre harvest diseases of fruits and vegetables as a result of these antimicrobial enzymes (Wei *et al.*, 2004; Cherif *et al.*, 1994b; Liang *et al.*, 2005). A significant reduction in postharvest diseases by silicon application was noted with respect to enhanced defensive enzyme activity (Qin and Tian, 2005; Bi *et al.*, 2006; Guo *et al.*, 2007; Liu *et al.*, 2009, 2010; Kumar and McConchie, 2010; Li *et al.*, 2012; Ebrahimi *et al.*, 2012; Polanco *et al.*, 2012; Farahani *et al.*, 2013; Polanco *et al.*, 2014; Kurabachew and Wydra, 2014). Root-applied Si significantly enhanced the activities of defensive enzymes, for example catalase, peroxidase, polyphenoloxidase and  $\beta$ -1, 3-glucanase in two asparagus cultivars, UC157 and Gynlim against stem blight caused by *Phomopsis asparagi* (Lu *et al.*, 2008).

### **Synthesis**

Silicon could be used to reduce many fungal diseases mildew (Powdery mildew and downy mildew), rots (fusarium root rot, phytophthora root rot, pink rot), mould (Blue mould, green mould, gray mould, white mould), blight (phytophthora blight and stem blight), and wilt (fusarium wilt, and anthracnose) in tropical fruits and vegetables. A few bacterial diseases (bacterial wilt) were also reduced by application of silicon. Many diseases observed in tropical fruits and vegetable were significantly reduced by silicon



application. However, gray mould in strawberry and blue mould diseases in some fruits grown in temperate countries (sweet cherry, peach, Jujube, apple, pear, oranges etc) were reduced by application of Silicon.

When considering the types of diseases and resistance enhanced by application of silicon in tropical fruits and vegetables, many records (75% of the published records) were available on reducing the powdery mildew disease in cucumber, muskmelon, Zucchini squash, pumpkin and about 25% of the published findings were available on reducing powdery mildew in disease in strawberry and grapes.

Silicon has been applied as a form of pre or post-harvest to reduce diseases in green mould or gray mould. But the postharvest application was done for reducing blue mould disease.

Foliar application of silicon has been used most effectively to reduce powdery mildew disease. However, blight disease was controlled by application of foliar or root.

The possible mechanism/s on diseases reduced by silicon could possibly be due to the formation of physical barriers by silicon depositions or by biochemical compounds formed or antioxidant defense enzymes formed.

Pre-harvest or post-harvest silicon application had shown a great potential in controlling diseases by inhibiting or delaying the growth and development of the mycelium of the pathogen. Powdery mildew infected leaf cells of silicate treated plants were exhibited to have extensive silica polymerization enhancing the thickness against the fungi in the halo region surrounding the site of fungal penetration

## **Conclusions**

Silicon has proven to be an effective means of reducing diseases in tropical fruits and vegetables. Therefore, the use of silicon could reduce the use of fungicides for controlling diseases.

The remarked alleviative effect of Si was recorded in controlling powdery mildew in cucurbits. Silicon might be effective in suppressing diseases in fruits and vegetables than bacterial diseases since preponderance of the findings were related to Si mediated fungal diseases than bacterial diseases. Silicon-induced resistance against infections is mainly attributed to the mechanical and chemical defense. In addition, SAR like mechanisms were involved in silicon induced defense in fruits and vegetables.

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- 1 Two-Dimensional Free Space Mesh Generation for Cloud-to-Ground Lightning Simulation using Finite Difference Method.  
***N. Kajaluxshy and S. Thirukumaran\****
- 23 Educational Environment for Undergraduate Medicine and Nursing Programme at Eastern University, Sri Lanka; Students' Perceptions  
***P. Youhasan\* and T. Sathaananthan***
- 37 Effect of Simulated Temperature and Water Stress on Growth, Physiological and Yield Parameters of Tomato [*Lycopersicon esculentum* var: Thilina] Grown with Mulch.  
***P. T. N. Dishani and C. S. De Silva\****
- 53 Maternity Legislation in Sri Lanka: Are Women Equal, Special or Different?  
***Sunethra M. E. Goonetilleke\****
- 79 Life with Lost Voice: An Exploration of the Experiences of Patients with Total Laryngectomy.  
***S. S. Rathnayaka, W. K. N. Sajeewani, H. A. S. Piyawardhana, N. K. S. M. Nissanka and B. S. S. De Silva\****
- 93 Effects of Global Warming Simulated Temperature and Water Stress on Fruit Quality of Tomato (*Lycopersicum esculantum*) Var.Rajitha.  
***M. D. M. Gunawardena and C. S. De Silva\****
- 113 Employability of Graduates of Public and Private Management Education Institutes: A Case Study of Two Institutes in Sri Lanka  
***K. R. Ambepitiya\****
- 135 Role of Silicon on Enhancing Disease Resistance in Tropical Fruits and Vegetables: A Review.  
***Darshani Weerahewa\* and Kosala Somapala***