

# Investigation of FM Radio Reception in Sri Lanka

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**Abstract** – A large number of state- and private FM radio channels are operating in Sri Lanka at present. A greater percentage of FM customers from Colombo and suburbs are the users of motor vehicles (both public- and private vehicle users). In villages, there are more house residents listening to radio. For household customers there exists the possibility of improving the reception qualities by improving the physical dimensions of the antenna elements whereas passengers of motor vehicles do not have that facility.

Since a large number of FM channels occupy a relatively low bandwidth the antenna can be very much sensitive to frequency changes. Hence the frequency sensitivity of an antenna has also been investigated here. Therefore, both the household customer and the vehicle user should also be able to do required adjustments to the antenna with a prior knowledge about the consequences of any maladjustments.

The article investigates the various possibilities of optimization of FM reception for both house residents and vehicle users.

The results show that the vehicle antenna changes its directional properties beyond a certain length. At longer antenna lengths a split in the vertical radiation pattern takes place. This property can be made use in the reception of channels at higher elevation angles.

The analysis also show that the household antenna array improves the multi-directional reception ability for high end frequency channels.

**Keywords:** Antenna, radio channel, FM reception

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## Nomenclature

SLBC - Sri Lanka Broadcasting Corporation

FM - Frequency Modulation

AM - Amplitude Modulation

VHF - Very High Frequency

UHF - Ultra High Frequency

## 1 INTRODUCTION

Radio broadcasting in Sri Lanka can be categorized mainly into two areas: Radio broadcasting and Television broadcasting. Radio Ceylon started regular radio broadcasting in 1947 which was renamed as Ceylon broadcasting Corporation (CBC) in 1967 by the Ceylon broadcasting act No. 37 in 1966. Medium Wave frequency band (526 kHz - 1606 kHz) was mainly used with AM (Amplitude Modulation) as the modulating technique.

With the introduction of TV broadcasting in 1979 the demand for radio programmes dropped drastically. Gradually number of TV channels increased, and the domestic radio

viewers dropped further. Domestic viewers became much more confined to remote villages where people have difficulties in watching TV due to various reasons.

SLBC continued with AM medium wave transmission until 1993. In 1993 SLBC switched to FM transmission (VHF lower band) from AM medium wave transmission.

With the increase of vehicles mainly in city areas of Sri Lanka, traffic congestion could be observed all over. As a mode of relaxation, the passengers of vehicles got more and more attracted to FM radio channels. More domestic FM users could be found in village areas compared to city area and suburbs.

With the increasing demand a large number of FM channels (both SLBC and private sector) have been introduced. Due to promotion schemes and various advertising campaigns by the private sector FM channels number of domestic FM listeners have been increased in city suburb areas and villages.

A good percentage of present TV channels are UHF channels, carrier frequencies become higher than 300 MHz. For FM transmission the average carrier frequency is around 100 MHz, thus wave length for FM transmission is approximately three times smaller than that of TV wave length. Therefore, the size of an ideal FM antenna (e.g. half wave dipole) becomes approximately 3 times larger than a TV antenna.

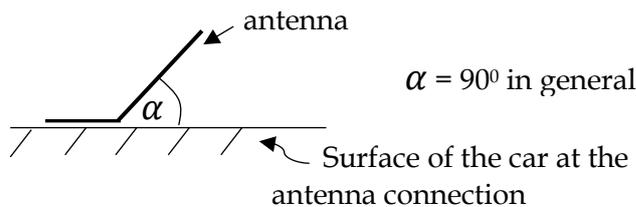
Another aspect to be considered in the design of a FM antenna is the frequency resolution of channels. FM sound quality is better than that of AM due to the fact that carrier frequency is less susceptible to channel noise compared to carrier amplitude. Due to large number of FM channels allocated in a relatively smaller bandwidth (87.8 MHz-107.5 MHz) the frequency resolution among carriers is relatively small. This can give rise to difficulties in tuning of FM channels. Proper selection of the antenna with appropriate dimensions can eliminate some of these difficulties and maintain a good sound quality.

As discussed previously there are two main categories of FM listeners. They are the domestic viewers and the passengers of motor vehicles.

Domestic viewers need an antenna installed at a higher elevation, in case the built-in antenna associated with the radio receiver shows poor performance. This is particularly true for remote areas. Once the antenna is installed it should be able to receive all possible FM transmissions covered in that area.

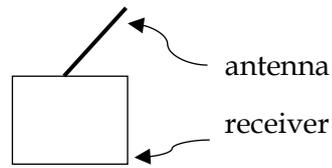
For passengers of motor vehicles situation is somewhat different. Since the antenna and the receiver change their positions with time, the signal reception by the antenna should be maintained satisfactorily irrespective of the location.

The antenna used in a motor vehicle is a *mono pole* type antenna whose length is normally adjustable.



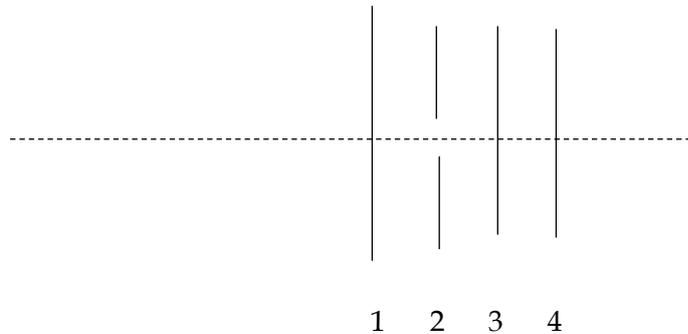
**Figure 1: Vehicle antenna**

In the case of a domestic user the receiver is provided with a similar type of adjustable monopole antenna.



**Figure 2: Domestic receiver**

The built-in antenna of the receiver does not exhibit good performance for most of the remote places. Therefore, a separate dipole antenna (with/without additional elements) has to be installed at a higher elevation. Since the type of polarization used in FM transmission is vertical polarization, always the antenna (and the additional elements) should be kept vertical.



**Figure 3: 4-element domestic antenna**

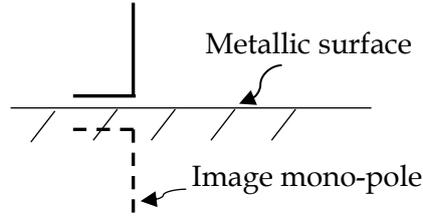
Various researchers have investigated the directional gain optimization problem for an array in the past (Cheng, et al., 1991 and Jason, et al., 2001). Research work has already been carried out to find optimum parameters of a Yagi array for the reception of multiple UHF TV channels (Perera, 2017).

The main objective of this research work is to investigate the performance of a domestic F.M antenna array and a mono-pole vehicle antenna under restricted conditions. It has been investigated here, how an antenna array designed for a particular frequency channel responds to high-end and low-end FM channels. Also, the impact of the antenna length on the directional properties of a vehicle antenna has been investigated in this paper.

## 2 THEORETICAL BACKGROUND

### 2.1 The mono-pole antenna

The mono-pole antenna used in a motor vehicle makes an image monopole using the metallic surface of the vehicle (surface on which the antenna is installed).



**Figure 4: Formation of a virtual dipole antenna**

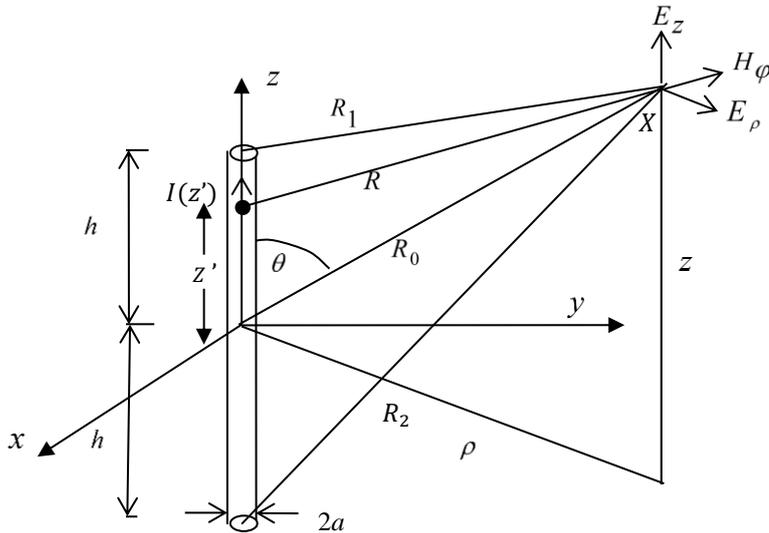
The antenna and the image together make a dipole antenna whose far field equation can be derived using Maxwell's equations.

## 2.2 Antenna equations

Starting from Maxwell's equations, equations for scalar potential  $\phi$  and vector potential  $A$  can be derived with the help of Gauge Transformation and Lorentz conditions (Ofandis et al., 2013).

In order to calculate the field components  $E_z(z, \rho)$ ,  $E_\rho(z, \rho)$  and  $H_\phi(z, \rho)$  it is sufficient to know  $A_z(z, \rho)$  the z-component of  $A$ .  $A_z(z, \rho)$  is given by

$$A_z(z, \rho) = \frac{\mu}{4\pi} \int_{-h}^h I(z') \frac{e^{-jkR}}{R} dz', \quad R = \sqrt{\rho^2 + (z - z')^2} \quad (1)$$



$\mu$  – permeability,  $\varepsilon$  – permittivity,  $k$  – wave number,  $2h_p$  – length of the  $p^{th}$  element

**Figure 5: Field components of a half wave dipole.**

Figure 5 shows various field components at a point  $X$  due to a half wave dipole. Using the relationship  $j\omega\mu\epsilon E_z(z, \rho) = \partial_z^2 A_z + k^2 A_z$  in the above equation with the assumption that  $I(z)$  is distributed sinusoidally, we can write  $I(z)$  as:

$$I(z) = I_0 \frac{\sin(k(h - |z|))}{\sin kh} = I_m \sin(k(h - |z|))$$

$$E_z(z, \rho) \text{ can be written as } E_z(z, \rho) = -\frac{j\eta I_m}{4\pi} \left[ \frac{e^{-jkR_1}}{R_1} + \frac{e^{-jkR_2}}{R_2} - 2\cos(kh) \frac{e^{-jkR_0}}{R_0} \right]$$

In a similar manner, field components  $E_\rho(z, \rho)$  and  $H_\phi(z, \rho)$  can be derived.

$$H_\phi(z, \rho) = \frac{jI_m}{4\pi\rho} \left[ e^{-jkR_1} + e^{-jkR_2} - 2\cos(kh)e^{-jkR_0} \right]$$

$$E_\rho(z, \rho) = \frac{jI_m}{4\pi\rho} \left[ \frac{z-h}{R_1} e^{-jkR_1} + \frac{z+h}{R_2} e^{-jkR_2} - 2\cos(kh) \frac{z}{R_0} e^{-jkR_0} \right]$$

Above field components can be used to calculate the normalized gain  $g(\theta, \varphi)$ , where  $\theta$  and  $\varphi$  are the elevation angle and the azimuth angle respectively. If sinusoidal distribution of current is assumed, polar gain  $g(\theta, \varphi)$  can be written as

$$\left| \sum_{p=1}^k I_p \frac{\cos(kh_p \cos\theta) - \cos kh_p}{\sin kh_p \sin\theta} e^{jkx_p \sin\theta \cos\varphi} \right|^2$$

In the case of a dipole antenna alone (without reflectors or directors) the value of  $k$  reduces to 1 and the gain of the antenna becomes equal to;

$$|g(\theta, \varphi)| = I_1 \frac{\cos(kh_1 \cos\theta) - \cos kh_1}{\sin kh_1 \sin\theta} \quad (2)$$

In an antenna array, the mutual impedance  $Z_{pq}$  on  $p^{th}$  element due to  $q^{th}$  element can be calculated from the  $E$  field strength at  $p^{th}$  element due to  $q^{th}$  element:

$$Z_{pq} = -\frac{1}{I_p I_q} \int_{-h_p}^{h_p} E_{pq}(z) I_p(z) dz$$

$I_p$  - current in  $p^{th}$  element,  $I_q$  - current in  $q^{th}$  element,  $2h_p$  - length of  $p^{th}$  element.

When  $p = q$ ,  $Z_{pq}$  becomes the self-impedance of  $p^{th}$  element.

This concept can be extended for an array consisting of  $k$  elements, so that we end up with an impedance matrix  $[Z]_{k \times k}$  consisting of self-impedances and mutual impedances.

$$[Z] = \begin{bmatrix} Z_{11} & Z_{12} & \dots & Z_{1k} \\ Z_{21} & Z_{22} & \dots & Z_{2k} \\ \cdot & \cdot & \dots & \cdot \\ Z_{k1} & Z_{k2} & \dots & Z_{kk} \end{bmatrix}, \text{ a matrix with diagonal symmetry } Z_{pq} = Z_{qp}$$

Since the voltage across the  $p^{th}$  element consists of self-induced voltage due to  $Z_{pp}$  and the induced voltages due to rest of the  $k-1$  elements,  $V_p$  can be written as

$$V_p = \sum_{q=1}^k Z_{pq} I_q, \quad p = 1, 2, \dots, k$$

Therefore, the voltage vector for the  $k$  elements can be calculated using the matrix equation

$$\begin{bmatrix} V_1 \\ V_2 \\ \cdot \\ V_k \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} & \dots & Z_{1k} \\ Z_{21} & Z_{22} & \dots & Z_{2k} \\ \cdot & \cdot & \dots & \cdot \\ Z_{k1} & Z_{k2} & \dots & Z_{kk} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ \cdot \\ I_k \end{bmatrix}$$

For an array consisting of a single dipole (only the active element), a reflector and  $k-2$  directors (then all  $k-1$  elements become passive elements), all the voltages in the vector except  $V_2$  become zero. If  $V_2$  is set to 1 unit, the voltage vector can be written as

$$[V] = [0, 1, 0, \dots, 0]^T, \text{ so that the currents in the elements } I_1, I_2, \dots, I_k \text{ can be calculated from } [I] = [Z]^{-1}[V].$$

These current values can be substituted in the equation for  $g(\theta, \varphi)$  to calculate azimuthal- and polar gains.

## 2.3 Polar- and azimuth radiation patterns of FM antennae

### 2.3.1 Motor vehicle antenna

Since the signals are vertically polarized, for a motor vehicle antenna (can be considered as a virtual vertical dipole) the azimuthal gain should be a constant. Therefore, the azimuthal radiation pattern becomes a constant.

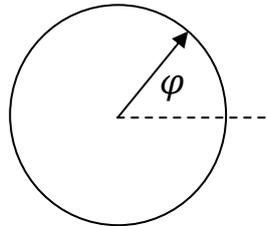
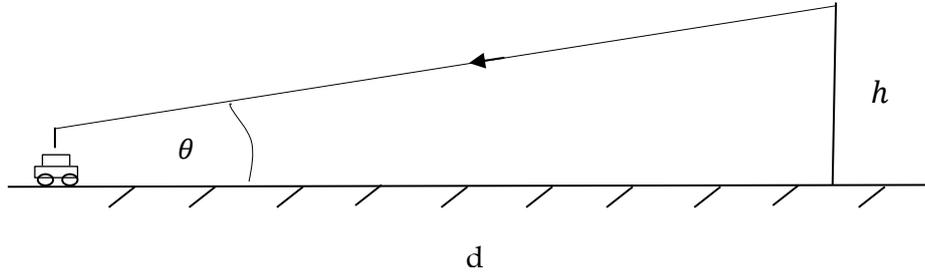


Figure 6: Azimuthal radiation pattern

The polar pattern can be plotted using (1). But it does not have much influence on the signal reception ( $g(\theta, \varphi) = g(0, \varphi) = \text{const.}$ ) if the distance between the receiving antenna and the transmitting tower is large.



**Figure 7: The influence of the elevation of the transmitting antenna**

If  $\theta$  is very small (ie.  $\frac{h}{d} \ll 1$ ), the azimuth gain can be considered a constant and hence the radiation pattern becomes a circle as shown in the Figure 6.

When  $\theta$  becomes larger directional properties of the polar radiation pattern plays a vital role.

### 2.3.2 Household antenna

A house hold customer will have to go for a fixed type directive, high gain antenna when the signal strength of region is weak. For example, a vertically polarized Yagi-array given in Fig.3 can be a good option. Such an array shows directional properties both in vertical- and horizontal planes.

## 3 METHODOLOGY

The investigation was mainly based on the polar radiation patterns of the antenna. The equation for  $g(\theta, \varphi)$  was used to plot the radiation pattern of the antenna. In the case of the motor vehicle, a single dipole was used for the simulation.

Polar radiation pattern was plotted for a range of values of  $h_1$  and investigated the directional gain behaviour. This behaviour was used to investigate the ability of the vehicle to receive FM channels when the transmitting tower is not far away from the vehicle.

For a household customer, simulation was done with a dipole array consisting of a single active element (dipole) and 3 passive elements. Here the main concern was to optimize azimuth gain. The length  $h_1$  was changed in the vicinity of  $\frac{\lambda}{2}$  to find optimum values.

MATLAB was used for all the simulation work.

## 4 RESULTS AND DISCUSSION

### 4.1 Motor vehicle antenna

When the physical antenna length ( $\frac{h_1}{2}$ ) is less than  $\frac{\lambda}{2}$  (i.e. when the total electrical length of the antenna  $h_1$  is less than  $\lambda$ ) antenna shows a polar radiation pattern without side lobes. This is very much suitable when the vehicle is far away from the transmitter.

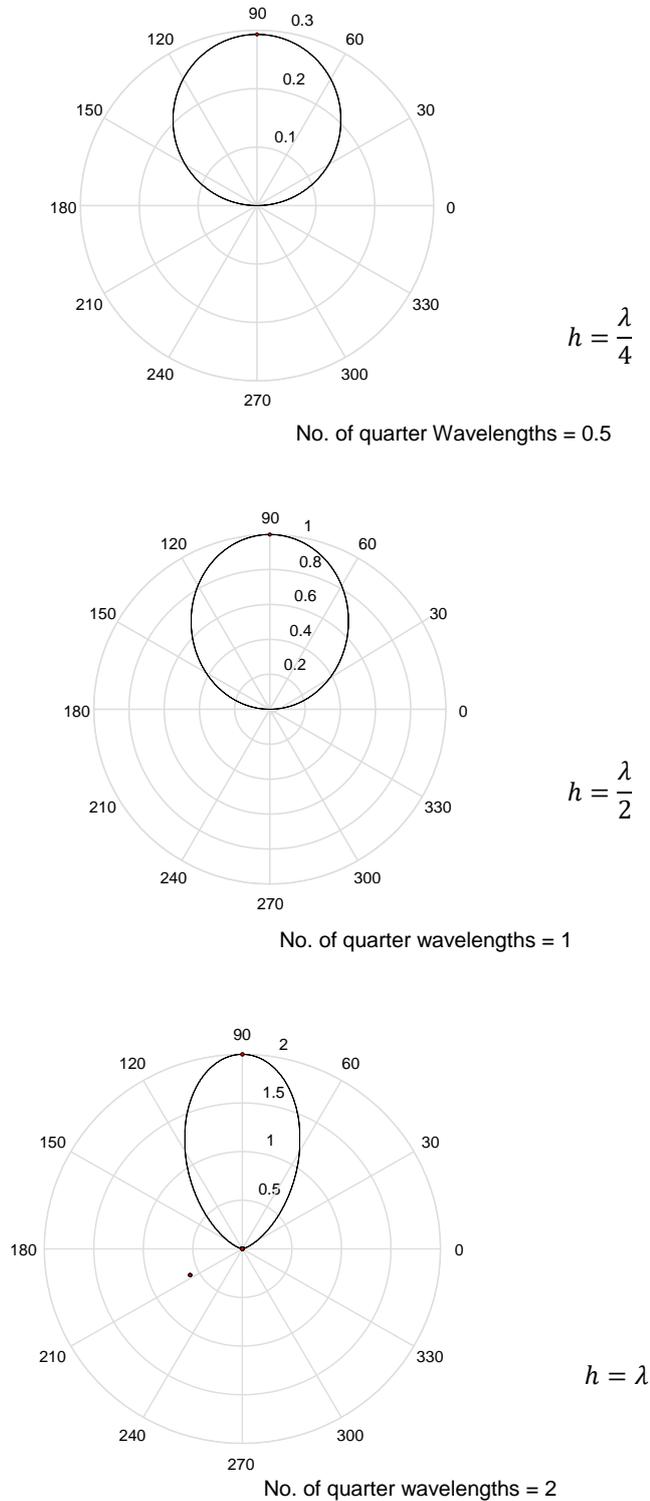


Figure 8: Polar radiation patterns for a vehicle antenna when *antenna length*  $\leq \frac{\lambda}{2}$

When the physical antenna length increases beyond  $\lambda$ , side lobe level starts to increase. When the antenna length becomes approximately equal to  $1.43 \lambda$ , in addition to the main lobe equally large 2 side lobes appear in the radiation pattern. One of these side lobes can be useful when the vehicle is closer to the transmitting tower.

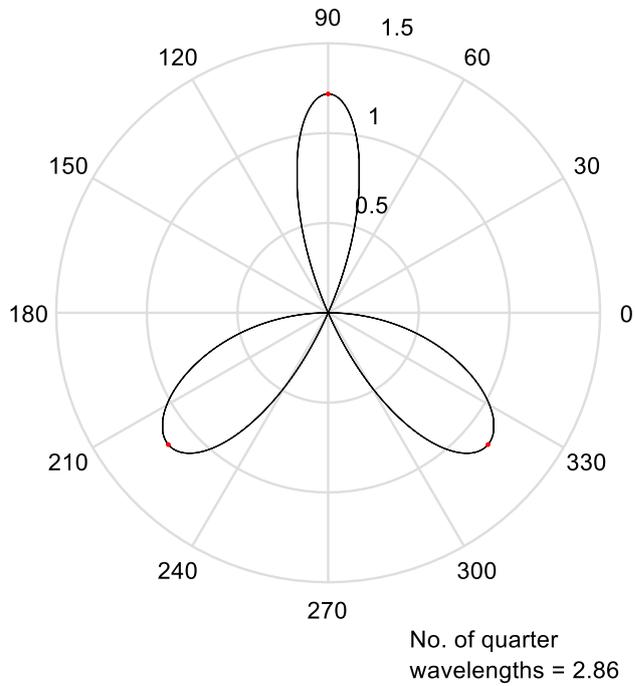
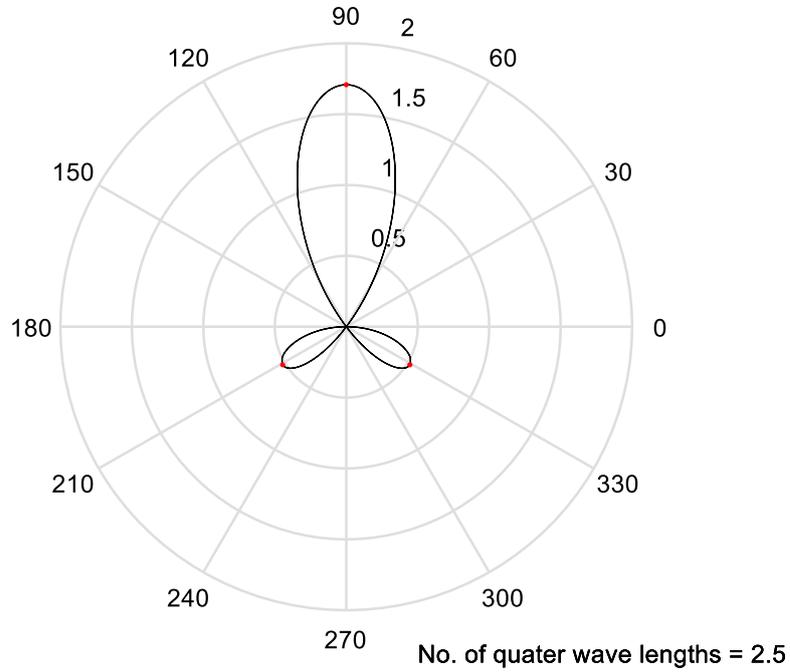
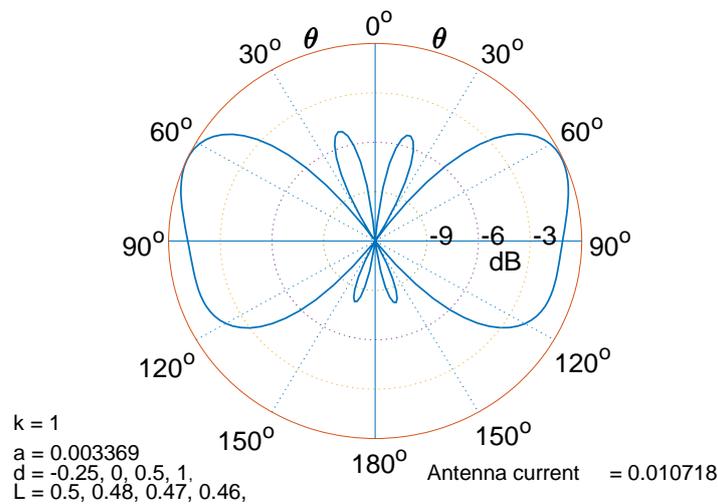


Figure 9: Polar radiation patterns for a vehicle antenna when  $antenna\ length > \frac{\lambda}{2}$

### 4.2 Domestic FM antenna

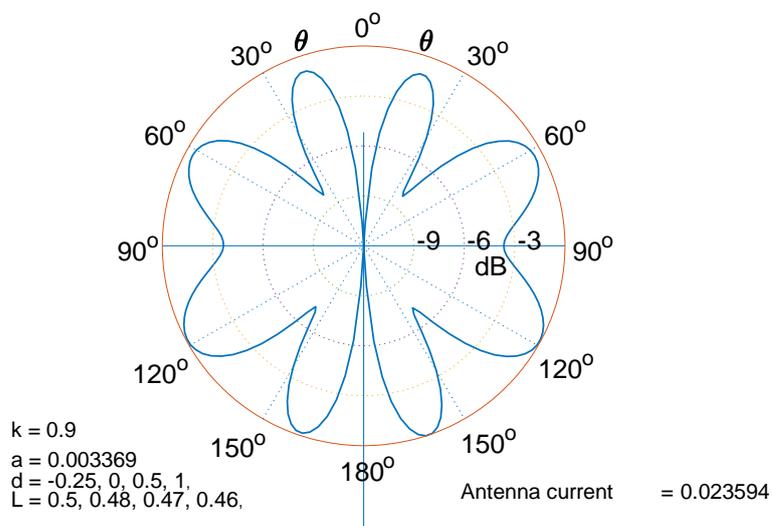
Results show that highly directive polar gain, with good a beam width can be achieved using a 4-element antenna with following specifications:

- The length of the dipole =  $0.48\lambda$ ,
- The length of the reflector =  $0.5\lambda$
- The length of the first director =  $0.47\lambda$
- The length of the second director =  $0.46\lambda$
- The spacing between the dipole and the reflector =  $0.25\lambda$
- The spacing between the dipole and the first director =  $0.5\lambda$
- The spacing between the first- and the second directors =  $0.5\lambda$

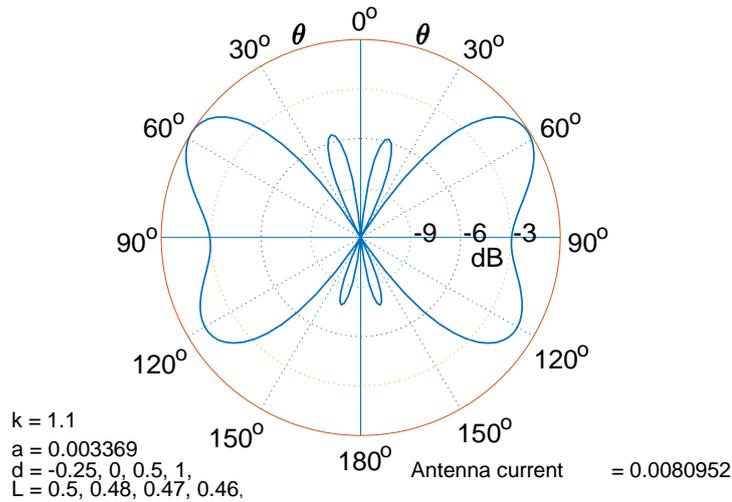


**Figure 10: Polar radiation pattern for a domestic antenna with 4 elements**

If the above antenna is somewhere in the middle of the local FM range (97.6 MHz), response of the antenna to lowest and highest frequencies (FM channels corresponding to 87.8 MHz and 107.4 MHz) can be plotted by changing the frequency by  $\pm 10\%$  or the wavelength by factors  $1/0.9 \approx 1.1$  and  $1/1.1 \approx 0.9$  as shown below:



**Figure 11: High frequency response of the domestic antenna**



**Figure 12: Low frequency response of the designed antenna**

The Figure with  $k = 0.9$  corresponds to an FM channel at high frequency end (ie. 107.4 MHz). This shows that the antenna beam width increases for FM channels at the high end.

## 5 CONCLUSION

The work here is mainly focussed on the areas where the FM reception shows some difficulties. In the case of vehicles FM reception is very much smooth in Colombo and suburbs. When car antenna length is adjusted its positive and negative repercussions are discussed in the paper. Due to the change in the current distribution pattern main lobe of the radiation pattern tends to split causing additional side lobes. One of these side lobes might be useful in the reception when the vehicle is closer to the transmitting station even though the antenna directive gain slightly drops. The signal strength of a car antenna is also dependent on the surrounding structures e.g. A congested road can change the received signal strength due to the signal reflections on the metallic surfaces of the vehicles. These factors were not taken for granted in this investigation.

In the case of a household antenna Yagi array with 4-elements shows good reception properties. It is interesting to observe that an array designed for a particular FM station shows higher beam width for higher frequencies. That is the multi-directional nature of the array improves while keeping the directive gain at an acceptable value.

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

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

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

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## 1 INTRODUCTION

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

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

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

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

## Objectives

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

## 2 METHODOLOGY

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

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

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

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

## **Growth parameters**

### *Germination rate*

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

### *Number of tillers per plant*

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

### *Plant height (cm).*

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

## **Yield parameters**

### *Panicle length (cm)*

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

*Number of filled grain per panicle*

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

*Weight 1000 grain (g)*

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

*Biomass weight (g)*

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

**Table 1: Treatment of the experiment**

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

*Days to maturity (days)*

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

*Harvest index*

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

#### *Yield (kg/ha)*

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

#### **Irrigation parameters**

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

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

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

### **3 RESULTS AND DISCUSSION**

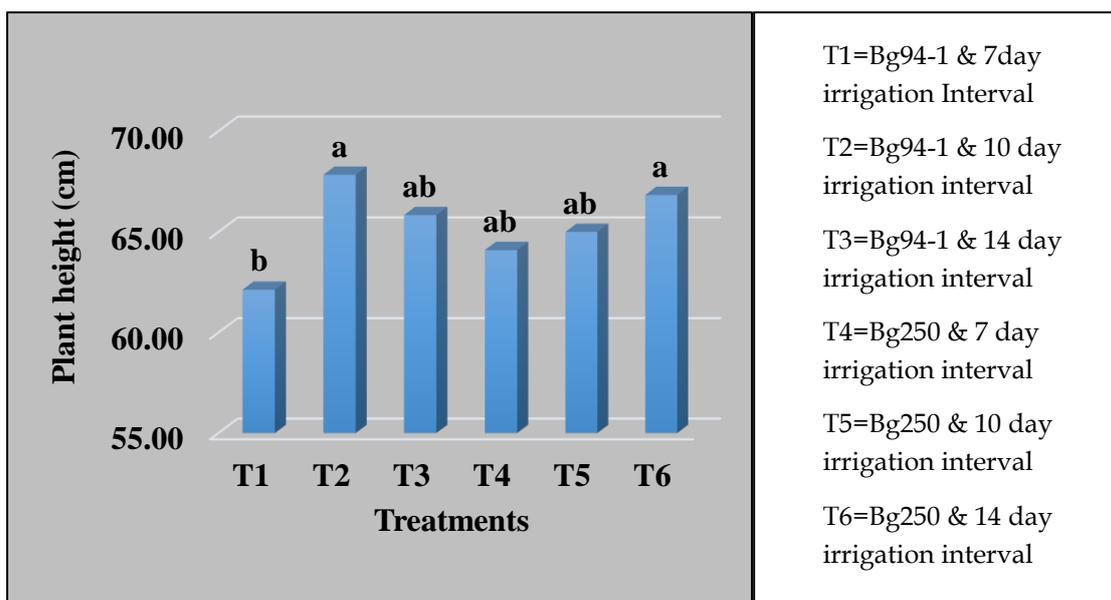
#### **3.1 Growth parameters**

##### **Germination rate**

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

##### **Plant height (cm)**

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



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

### Number of tillers per plant

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

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

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

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

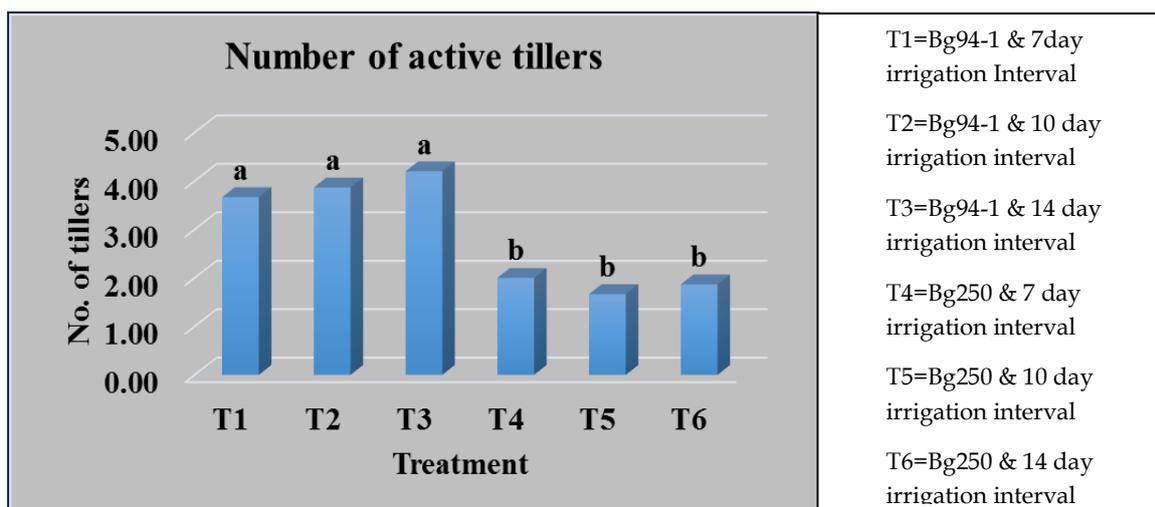


Figure 2: The average number of tillers per plant for different treatments

### 3.2 Yield Parameter

#### Panicle Length (cm)

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

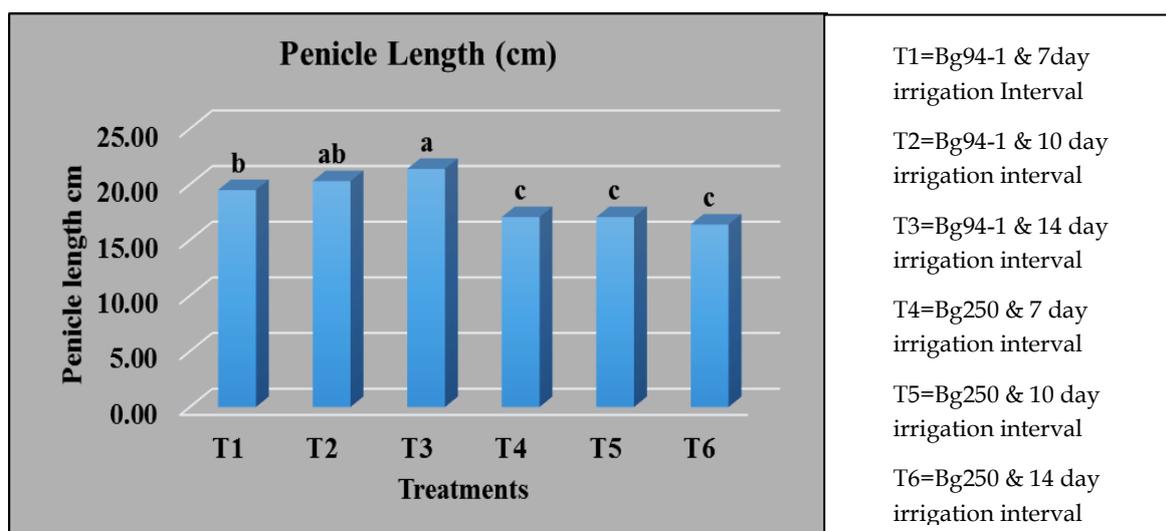


Figure 3: Average panicle length of the treatments Means with the same letters do not differ significantly ( $p < 0.05$ )

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

### Number of filled grains per panicle

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

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

### Weight of 1000-grains (g)

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

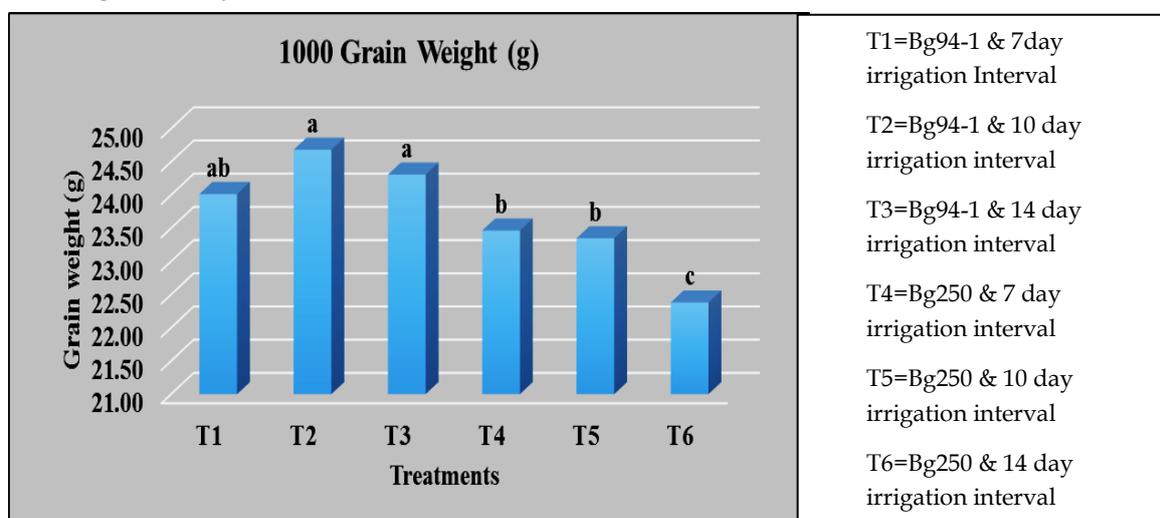


Figure 4: Weight of 1000-grains (g) of the treatment

### Fresh biomass weight (g)

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

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

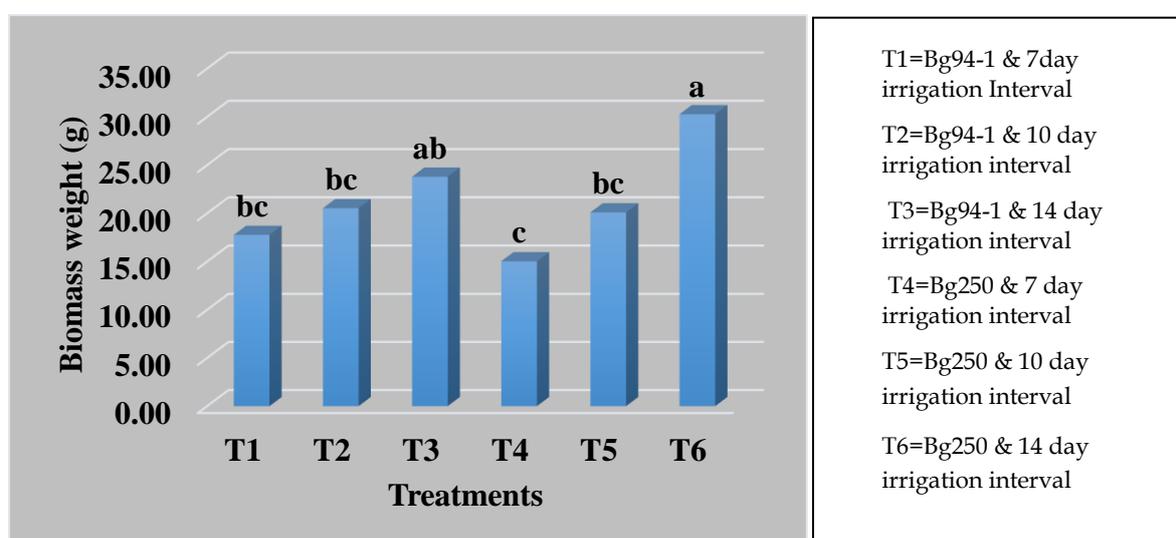


Figure 5: Average biomass weight (g) of the treatments

### Grain Yield (kg/ha)

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

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

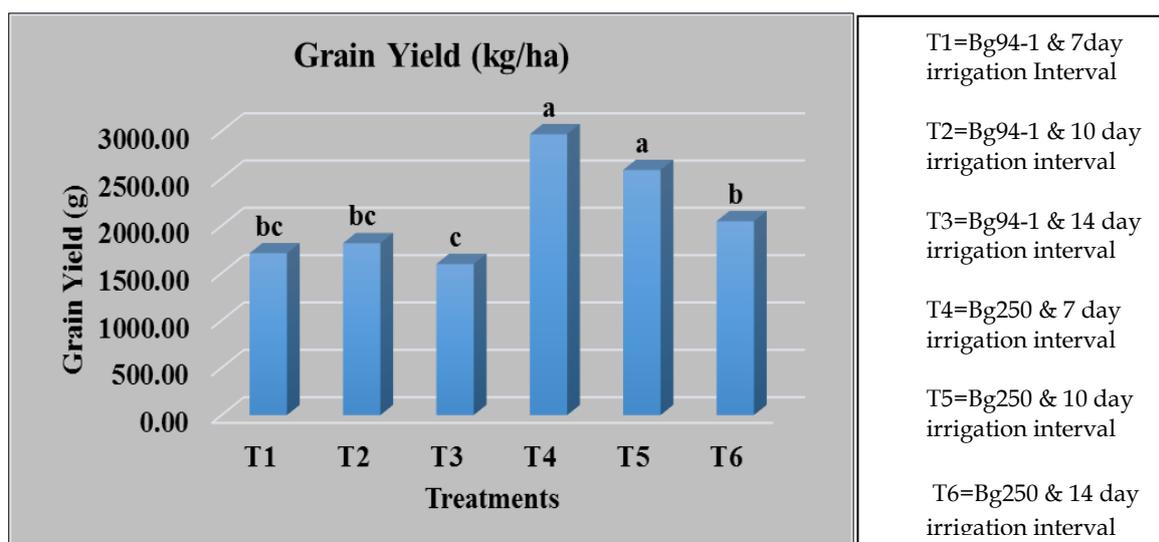


Figure 6: Average Grain Yield (kg/ha) of the treatments

### Days to Maturity

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

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

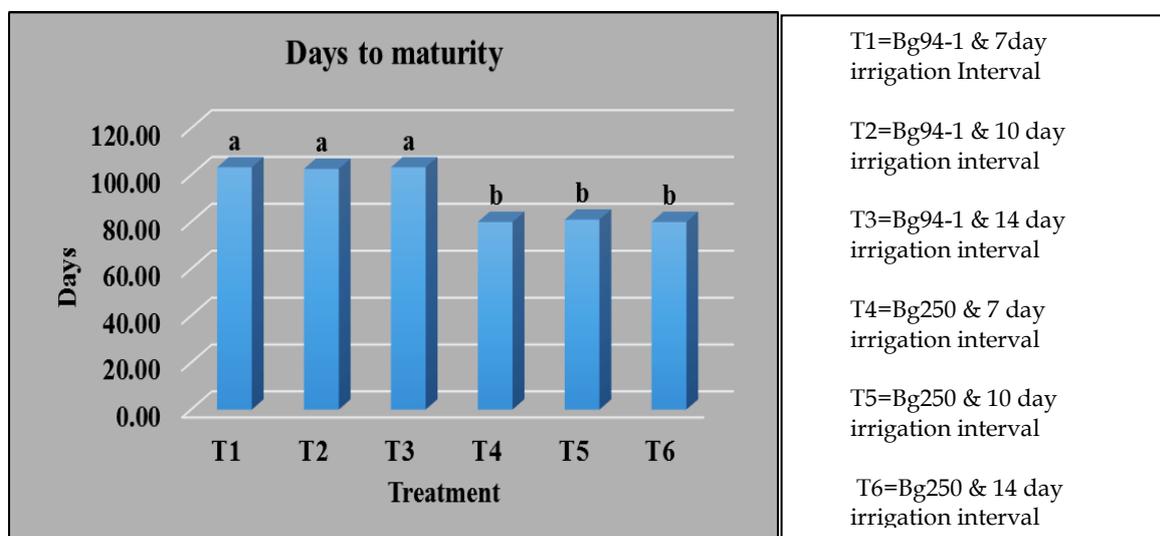


Figure 7: Days to maturity of the treatments

### Harvest Index

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

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

### 3.3 Irrigation parameter

#### Cost of irrigation

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

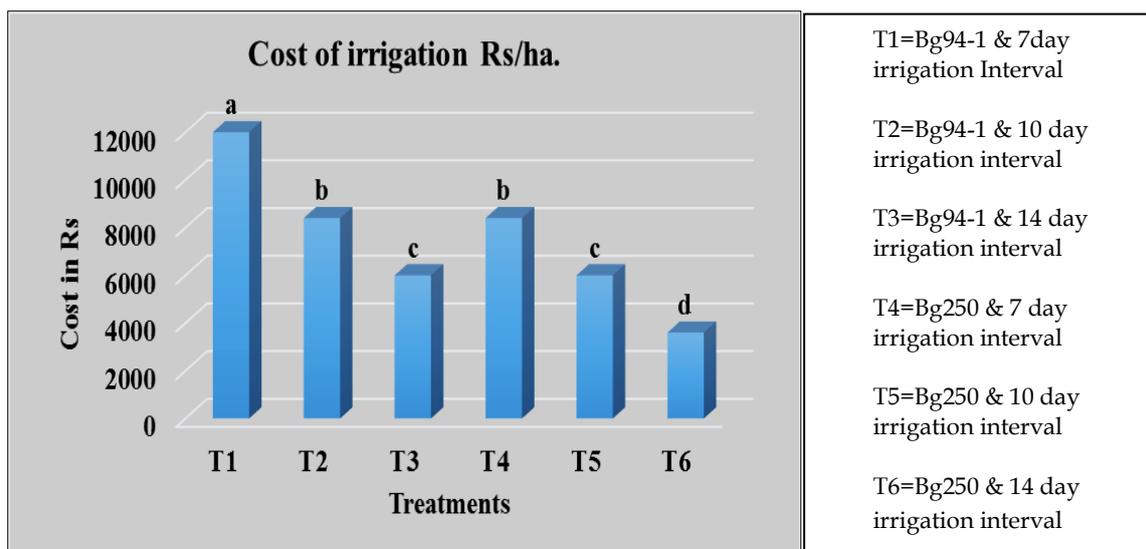


Figure 8: Irrigation cost per acre in rupees for different treatments

### Net Profit

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

Table 2: Cost of irrigation and net profit analysis

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

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

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

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

#### 4 CONCLUSIONS AND RECOMMENDATIONS

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

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

#### ACKNOWLEDGEMENT

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# A Study to Find out The Suitability of Nuclear Power Plant to Sri Lanka

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**Abstract** – Power plants with larger capacities should be introduced to the system to meet the future demand of the country. This paper discusses the possibility of introducing nuclear power plant (NPP) to meet this demand. Since the nuclear power plants are based load plants base load of a system should be sufficient to operate NPP. The paper analyses future demand of the country to see the feasibility of NPP to Sri Lankan power system. The paper also discusses different technologies for NPP and type of reactor that may be suitable for Sri Lanka. The paper analyzes the possible locations of NPP considering factors that are affected in deciding locations for NPP. The aspect of radioactive waste management which is one of critical aspects in NPP operation has been also discussed. The options available for the NPP to the exiting grid also are a part of this work.

**Keywords:** Nuclear power plant, base load power

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## 1 INTRODUCTION

Presently, nuclear energy contributes about 11% of electricity generation and more than four hundred nuclear reactors are being operated successfully in thirty-one countries around the world. Installation of a nuclear power plant to the Sri Lankan power system has been actively discussing for number of years. However, installation of NPP to Sri Lanka is still debating due to the factors including technical, environmental, economic, social and political.

Increase of population, living standard of the people, 100 % electrification, infrastructure development, and establishment of different types of industries lead to increase of electricity demand in the country. The country should have both short and long term generation plans to meet this demand. Future energy crisis in the country can be avoided only having a proper generation plan and its implantation.

At present, electricity demand is met by mixture of hydro, thermal (coal, gas turbine) diesel power plants together with certain percentage of electricity generation from non-conventional renewable energy (NCRE) sources (solar, wind). The economic viability of further addition of both coal and diesel power plants to the system in long term may become questionable due to depletion of fossil fuel and increase of their cost. In addition to this fossil fuel based power plants produce Green House Gases (GHG) such as Sulfur Dioxide (SO<sub>2</sub>), Nitrogen Dioxide (NO<sub>2</sub>) and Carbon Dioxide (CO<sub>2</sub>). The emission of these GHS becomes a threat to the environment and causes global warming. Even though the

regulations have been imposed to minimize the environmental impact, there are environmental issues in the area surrounding the existing coal power plant.

Larger portion of electricity generation of the country comes from the hydro power plants. Even though hydro power plants do not produce GHG the electricity generation highly depends on the weather conditions. During last few years the country has been experiencing energy deficit due to draught weather conditions. In addition to this the possibility of future construction of high capacity hydro power plants in the country is very minimum due to lack of locations with the capability of storage of water in large amount.

Utilization of NCRE for electricity generation has been increased significantly during last few decades. However, the electricity generation from both solar and wind is highly depending on climate condition. The unit capacity of these plants also is limited due to technical limitations. Macro systems like power systems needs power plants with larger capacity to maintain the stability of the system. On the other hand still the efficiency of these non-conventional power plants are low and their cost is high and therefore the unit cost of energy produced by the non-conventional power plants is of higher value. This means still the conventional power plants with higher capacity has an essential role to play in a power system.

With the increase of the demand and due to limitations and certain disadvantages of the currently used power plants, the NPP may be a good potential candidate to meet the future electricity demand of the country. The operation of NPP involves the emission of radioactive product and therefore safety and environmental issues play a crucial role on deciding the construction of nuclear power plant. This paper discusses type, capacity, location, type of the NPP and social and environmental issues related to the operation of NPP.

## **2 SYSTEM CAPACITY**

By year 2034, thermal power capacity retirements will be 1023 MW and total installed capacity will be 8032 MW (without adding Non-Conventional Renewable Energy (NCRE) portion total capacity will be 6616 MW). The peak demand will be 5692 MW. NPP are considered as based load power plants. The installed capacity of NPP depends on the base load of the system load curve. This means there should be a sufficient amount of base load for the NPP. Presently base load of the demand curve is about 1100 MW. Considering the average growth rate 5.3% of the demand forecast, the base load demand can be estimated as 2600 MW in 2034. It is clear that more generating plants should introduced the system to cover this load (Ceylon Electricity Board, 2015). Figure 1 shows the contribution of different types of power plant to meet the predicted demand in year 2030.

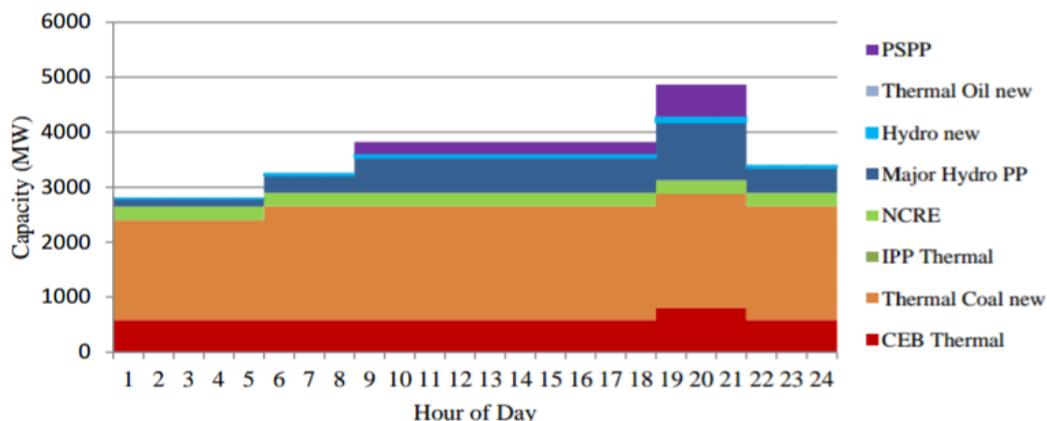


Figure 1: Capacity contribution from power plant in a day in March/April 2030 (Ceylon Electricity Board, 2015)

### 3 NPP CAPACITY

According to the largest unit index, capacity of the largest unit should be smaller than 900 MW by 2034, but there were number of suggestions for establishing coal power plants in Sri Lanka according to the CEB long term generation expansion plan. The capacities of the most plants are about 300 MW because it is a disadvantage to install larger capacity power plants in Sri Lanka even when considering the capacity. One of the major issues that need to be considered is the capacity of a nuclear power plant. The nuclear power plants are to cover the base load of the system. The reason is that the plants are not suitable for frequent starting or stopping. This means the capacity of a nuclear power plant should be less than the base load of the system. Since the base load of Sri Lankan system is not expected to be a very large one, the NPP capacity also should be a relatively smaller one.

Based on the capacity, nuclear reactors are grouped as smaller, medium and larger reactors. The reactors with electrical capacity of less than 300 MW or thermal capacity of less than 1000 MW are known as small size reactors. Small size reactors have several advantages compared to large size reactors. Constructions, land area, plant requirements and impacts (specially cooling water impacts) are less in small size reactors than medium or large size reactors. Considering the geographical area and the amount of the base load in the total load curve small size reactor is more suitable for the country. Handling of smaller capacity reactors is easier than handling the larger capacity reactors. Small size reactors are better matching of system demand growth and they have smaller unit capital cost.

### 4 NUCLEAR REACTOR

There are several reactor types is being used by several countries, such as Light Water Reactors (Pressurized Water Reactor and Boiling Water Reactor), Pressurized Heavy Water Reactor (PHWR), Advanced Gas Cooled Reactor, Graphite Moderate Light Water Reactor and Fast Breeder Reactor. Among these reactor types, PHWR scores higher mark because this reactor has several advantages than other reactor types.

#### **4.1 Basic advantages of Pressurized Heavy Water Reactor**

- Use natural Uranium ( $UO_2$ ) as fuel, therefore fuel cost is less expensive and spent fuel can be store more compactly
- Ability to refuel while on load is a special feature, this increase duty cycle and capacity factor of the plant
- This reactor has indirect cycle, therefore no radioactivity involve in secondary cycle
- Reactor consists of full double containment design. It increases the safety
- Reactor vessel is not single vessel type, therefore transportation is easy
- This reactor consists of two independent shutdown systems
- Lay out of the plant is designed for twin unit modules, therefore some auxiliary systems can be shared by both units
- Reactor consists of several auxiliary systems and safety procedures

Mainly PHWR are operated in Canada (CANDU), India, and China. In India the first two units (Rajasthan Atomic Power Station units 1 & 2) were imported from Canada. They are based Douglas point. Due to the failures of these reactors India constructed standard Indian Pressurized Heavy Water Reactors (IPHWRs). They are based on CANDU technology. India has built 220 MW, 540 MW, 700 MW small and medium size reactors. Sri Lanka government has signed a nuclear corporation agreement with India in 2015 and also India is the nearest country to Sri Lanka. In India sixteen 220 MW IPHWR are successfully operated (Muktibodh, 2011). The plant layout of Indian PHWR has been developed on the basis of twin unit concept (Therefore total capacity of this plant is 440 MW).

### **5 IDENTIFICATION OF THE SUITABLE LOCATION FOR THE NUCLEAR POWER PLANT**

Location of a nuclear power plant should be selected very carefully considering various aspects. Since the nuclear power plants deal with radioactive product the location should not be a living area. Even the place is far away from the living area the people in the region may dislike having a power plant in the area. A good example for this may be the objections from different societies within Sri Lanka for NPP in South India. The same can be expected when the power plant is proposed within the country.

The selected location also should be free from natural disaster such as earthquake, tsunami. The reason for the disaster of the Fukushima Daiichi nuclear power plant in Japan in 2011 was this type of natural disaster. Even though the hundred percent guarantees from the natural disasters cannot be given, the locations should be scientifically verified the probability of having disaster.

Radioactiveness of waste product of the nuclear reaction remain number of years, therefore, storage of the radioactive product also is an important aspect. In countries where the nuclear power plants are in operation this is done in number of ways such as near

surface disposal and deep geological disposal, deep boreholes, Ocean floor disposal, etc. Considering above facts the plant location should be done very carefully. Some of the general factors are listed here.

### 5.1 General Factors

- Geology and Seismology - area should be free from geology and seismic hazardousness
- Tectonic structure - seismic hazard of Sri Lanka is very low because it does not lie near any of plate boundary
- Hydrology - A NPP requires reliable source of water for the cooling purposes and other plant requirements
- Demography - Low population area is most suitable
- Climatology - Coastal area Climatology is quite suitable for the plant
- Public acceptance - anti nuclear movement can be come as direct action groups, environmental professional organizations

The site survey was carried out in three steps. First the regional analysis was done by considering the general factors. Then potential sites were selected. Candidate sites were found out by screening potential sites according to the general factors and special factors. And according to the gathered data it was found out which candidate sites are most suitable to establish a nuclear power plant. Below is the list of 6 candidate sites which have been analyzed and explained. Table 1 shows potential suitable sites for the nuclear power plants.

**Table 1: Candidate sites**

Location	District	Area (km <sup>2</sup> )	Population	Pop. density per km <sup>2</sup>	Distance to pop. area (km)
Delft island	Jaffna	45	3,824	84.98	40
Lahugala	Ampara	815	8,914	10.94	15
Musalai	Mannar	475	8,119	17.09	21
Manthai west	Mannar	608	1,477,1	24.29	18
Vakarai	Batticaloa	584	2,153,7	36.57	21
Maritemepattu	Mulativu	600	2,897,3	49.29	20

## 5.2 Selected location

By considering sociable and environmental involvements, Delft Island is selected as most suitable location for the NPP, because those involvements can be less in this area than other selected areas. This island is 40km away from main land and this will be very useful to get public acceptance when considering protection zones around the plant. Delft island is famous for wild horses, heritage, agriculture (coconut) and tourism. This area consists of many fishing villages. Electricity scheme will not meet the requirement of 1082 families and frequent power disruptions. Houses are fenced by coral- stones piled up or by Palmyra leaves. This island is underdeveloped. Roads are not crowded. Population of this area is low and few number of families have to be relocated. And also small island around the delft island can be used for the plant purposes such as spent fuel disposal and store new fuel, etc. Inland water distribution is very low and fresh water for some areas are supplied by army from main land. But according to a research carried out by Jaffna university, they have found inland ponds, but those water sources will not enough for the plant requirements. Therefore desalination plant may be better solution for this problem.



Figure 2: Delft Island

## 6 ENVIRONMENTAL AND SOCIABLE IMPACTS

### 6.1 Impacts of land

Impacts on land used are mainly based on the exclusion boundaries of NPP. The people who live on these exclusion zones have to be relocated and the cultivation process must be shifted to another area owing to the boundaries even though the plant footprint is small. Some of lands are agricultural lands, therefore effects due to loss of those lands must be taken into account.

## **6.2 Impacts of the cooling water and waste water**

Discharge cooling water that use in the power plant will increase the temperature of the sea water close to the discharge place (this used cooling water doesn't include any radioactivity), this slightly temperature increase of the sea water will not do any significant effect on fish mitigation. But turbidity due to construction activities may cause to fishery mitigation.

## **6.3 Impacts of radioactive and other emissions**

All the emissions are released to the environment in control manner and after reduce to set limits, and also these emissions are so low (normal operation set limit 0.1 mSv/year).

## **6.4 Impacts of living condition and health**

Someone just exposed to about 0.03 mSv of radiation living near a power plant for a day, and also of someone lived within 50 miles of a NPP, he would receive an average radiation does about 0.0001 mSv per year, normally the average person in US receive a 3 mSv per year (IAEA, 1996).

## **6.5 Impacts of landscape and cultural environment**

This impact will be caused by heavy traffic required by the transport of large building parts and its requirements, new road connections and the improvement of current roads. All the selected areas are coastal areas and most of the areas are famous for tourism and holiday residues, but these industries will be no longer possible.

## **6.6 Impacts of the waste management and waste disposal**

Nuclear waste disposal doesn't have any negative effect if it disposed properly. Nuclear waste is located in the storage place for many thousands of years until it is no longer radioactive and dangerous. However, there can be large impacts from nuclear waste disposal if the nuclear waste is improperly disposed. There is no easy or simple way to clean up spilled radioactive materials and also that area takes several years to ensure that it is safe to live or even visit again.

## **6.7 Impacts of the decommissioning of the power plant**

The impacts of decommissioning of NPP remains low, there must be radiation protection to the people that participate in the decommissioning process. The generate waste during the demolition phase may be similar to the generated waste during the operation of the plant.

## **6.8 Impacts of people and society**

Good social impacts and bad social impacts can be occurred due to NPP, because lots of labors are needed to the plant construction at the construction stage. Form the population details of the selected areas, the large potion has gone to the young age group. For an example, Employment for youth and means of livelihood are the major demands of Delft Island. Therefore these people will be able to get jobs owing to a NPP. Another important thing is the area will be well developed (new roads, ports, and buildings will be constructed). The bad impacts are causeless fear of people and negative attitude of societies against NPP.

## 6.9 Impacts of accident condition

International Atomic Energy Agency (IAEA) has defined that a NPP accident as an event that release radioactivity with significant consequences and including harmful does to human and soil contamination. Most of the people have a fear about the accidents of NPP, but Sri Lanka is an Island near to India and also the Kudankulam Nuclear Power Plant in Tamil Nadu is only 225 km away from Sri Lanka (Kalpitiya). Therefore Sri Lanka is already located at NPP region.

## 7 LIFE CYCLE COST (LCC) ANALYSIS OF NUCLEAR POWER PLANT AND COAL POWER PLANT

LCC assessment involves the estimation of major expected costs within the useful life of a power plant. This calculation allows comparison of different investment alternatives and thus enables determination of the most cost effective system.

$$\text{Specific Life Cycle Cost} = \frac{P+Md}{8760.C.d} + f + m \text{ per kWh}$$

where,

P - Capital cost including Interest During Construction (IDC) per kW

M -Fixed Operation & Maintenance (O & M) cost per kW

d -Present Value factor corresponding to the economic life of the plant

f - Fuel cost of a kWh of electricity generated

m- Variable maintenance cost per kWh of electricity generated

### 7.1 Life cycle cost of NPP and Coal Power Plant (CPP)

**Table 2: Cost values of Plants**

Cost	IPHWR - 220 MW (US\$/kWh)	CPP (275 MW) (US\$/kWh)
Capital cost (with fixed O & M cost)	0.02807	0.03762
Variable maintenance cost	0.00261	0.00349
Fuel cost	0.00518	0.02785
Life cycle cost	0.03586	0.06896
	5.49	10.5964

LCC of the Nuclear power plant and Coal power plant is 5.49 LKR/kWh and 10.5964 LKR/kWh respectively. The LCC of the Nuclear power plant is quite small than LCC of

the Coal power plant. Here, environmental pollution control methods of the Coal power plant have not been considered.

Cost values of unit IV reactor of Kaiga Atomic Power Station were considered for this cost analysis. This plant was commissioned in 2010. But as an assumption authors have considered as this plant was started in the current year. And also cost data of Lakvijaya coal power plant project were used and as an assumption author has considered as this project also started in the current year.

## 8 NUCLEAR WASTE MANAGEMENT

Radioactive waste can be categorized according to its activity level and the radioactive half-life radionuclides it contains. The main types of waste are Low Level Waste (LLW), Intermediate Level Waste (ILW) and High Level Waste (HLW). The LLW is comprises paper, clothing, tools, gloves, plastic containers, etc. This LLW is not dangerous to handle but carefully disposed than normal garbage. The volume of LLW is 90% of the total volume of the waste but contains only 1% of the radioactivity (short lived radioactivity). This waste doesn't require any shielding during handling and transport. ILW is more radioactive than LLW. But generated heat ( $< 2 \text{ kW/m}^3$ ) is not rather high for design special storage or disposal. But this waste requires some shielding. This waste contains radioactive resin, chemical sludge, metal fuel cladding, and containment materials from reactor decommissioning. The volume of ILW is 7% of the total volume of the waste but contains only 4% of the radioactivity.

HLW is considered as the used fuel assemblies (spent fuel) taken out from the reactor during the refueling process and decommissioning of the plant. This waste contains highly radioactive radionuclides (long half-lives). The volume of HLW is 3% of the total volume of the waste but contains 95% of the radioactivity. The radioactivity level of fuel assembly has been analyzed as 92.5 TBq/kg and it takes 10 years (Spent fuel pool inside the fuel building) for drop to 14.8 TBq/kg, after 100 years radioactivity will be dropped to approximately 1.85 TBq/kg.

### 8.1 Nuclear waste disposal options

Various processes are used to treat Low and Intermediate Level Waste (LILW). The treatment process is depends on the nature and radioactive level of the waste. Most of the activity present in the form of Cesium ( $^{137}\text{Cs}$ ), Cobalt ( $^{60}\text{Co}$ ), Ruthenium ( $^{106}\text{Ru}$ ). The main focus of these processes is waste volume reduction. Commonly used LILW treatment processes are Chemical treatment process, Treatment using solar evaporation, Ion exchange and Treatment by membrane process. After the treatment process, the waste should be disposed. There are several ways to use for disposed LILW. Such as near surface disposal, sea dumping, incineration, etc. but sea dumping and incineration can cause large harm to environment. Therefore near surface disposal is acceptable. Near surface disposal is done at ground level, or in caverns below ground level (10 m depth). Ground level disposal is suitable for the Sri Lanka because capacity of the plant is not very high.

There are two main methods have been used for the HLW disposal. They are mined repositories and deep borehole. Mined repository is the oldest method of deep geological disposal and many countries have been using this method for dispose HLW. The depth of this disposal is between 250 m and 1000 m. Mined repository consists caverns or tunnels into that packaged waste would be placed. Multiple barriers should be applied for the fuel

assembly for reducing the heat and radioactive products to the environment. For the digging of deep underground repository using standard mining or engineering (eg: under land or near shore), most suitable types are rock units without major underground water flow that are stable and safe. Potential host rocks are rock salt, clay/ argillaceous rock and crystalline rock. Rock salt is the most suitable because it has higher thermal conductivity and high resistance.

Deep borehole disposal method has been developed (but not implemented yet) in several countries. It is more protective concept than mined repository. But stored fuel cannot be reused again. Deep boreholes are narrow, vertical holes drilled deep (depth of up to about 5000 m) in to the earth. 400 steel canisters can be contained in a single borehole of disposal zone (each canister is 5 m long and one third to half meter in diameter). This is more effective method for low volume waste and this will be expensive for the large volume of waste. These boreholes can be drilled off shore as well as on shore in both crystalline and sedimentary host rocks.

Those methods are suitable for the HLW disposal in Sri Lanka. But deep borehole method is most suitable because capacity of the selected plant is not very high. Therefore waste will be less. But this deep borehole concept is still under development state. Most of the countries expect to replace mined repository disposal options to borehole disposal. By considering the protection to environment and people, deep borehole disposal scores high mark than mined repository disposal. Mined repository also better way to dispose HLW. But protection is less than deep borehole disposal.

## **8.2 Suitable site for the waste disposal**

Site selection for the waste disposal should be done very carefully. There are some special factors to be considered before selecting a site for the disposal. These factors are free from earthquake threats, the area must be isolated area and underground water flow should be less, Low risk of flood and natural disasters, etc.

The selected location for the plant is Delft Island. This delft island is free from above factors. Total land area of the area is 45 km<sup>2</sup> and all the people should be relocated in another area. Therefore whole island can be used for the plant purposes (only 25 hectares are belongs for the plant footprint). Therefore some part of this island can be given for the waste disposal. The delft island consists of coastal vegetation, dry pasture land, managed home gardens, Palmyra wood land, thorn scrub jungle, and wet pasture land. Underground water distribution also less in this area. Mined repositories and deep borehole disposal can be implanted onshore, near shore or offshore. Therefore part of this island can be used for this purpose.

## **9 LOAD FLOW ANALYSIS**

The load flow analysis was done by using PSS/E software. Transmission network of the upper part of country was taken for the analysis because selected location was Delft Island and the nearest grid was Chunnakam grid substation. Twelve of 132 kV grid substations (Chunnakam, Kilinochchi, Vavunia, Anuradhapura, Puttalam, Trincomalee, Habarana, Ukuwela, Kiribathkubura, and Kurunegala) and one 220 kV grid substation (New Anuradhapura) were added for this load flow analysis. The selected unit total capacity was 440 MW (2 × 220 MW PHWR). High power has to be transmitted through the cables

(distance is 156 km to New Anuradhapura 220 kV grid substation). Therefore new transmission voltage was calculated using empirical formula of voltage selection. The selected transmission line voltage was 400 kV. Therefore new two 400 kV grid substations were implemented. Generation voltage of the plant is 12.5 kV, this voltage is step up to 400 kV and 132 kV through three winding transformer and 132 kV line was connected to 132 kV Chunnakkam grid substation and Delft 400 kV switchyard was connected to the New Anuradhapura 400 kV grid substation (implemented).

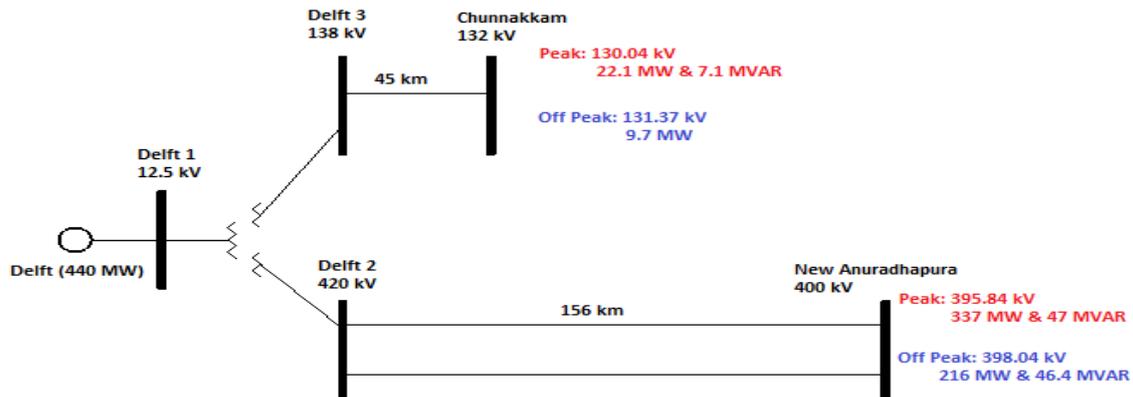


Figure 3: Transmission line connections to grids from Delft

## 10 CONCLUSION

NPP can be considered as one of potential candidate to meet the future based demand of the Sri Lankan power system.

At present the base load is not sufficient for the NPP, that is considered as base load power plant. However, according to the load growth there will be sufficient base load for NPP after ten to fifteen years. As per the literature review and the current practice of NPP in other countries smaller type reactor will be most suitable type of reactor for NPP in Sri Lanka.

Location of the NPP is one of the important aspects since general masses of the people do not accept the construction of a plant nearby. Considering this fact, the locating NPP within the main island may face a lot of opposition from the people and it might become a social and political issue. Therefore, one of the solutions for this is to locate NPP in a small island in the northern sea of the country. The island can be isolated from the people by shifting residence of the island to some other places. The water requirement for the NPP can be met using desalination of sea water. According to the land area of the island the part of the island can be utilized for the disposal of radioactive waste.

The analysis shows that the capacity of the NPP is 440 MW and it is suggested to connect the NPP to the national grid by two lines: 132 kV at Chunnakkam and 400 kV New Anuradhapura.

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# Impact of Irrigation Methods and Mulches on Chilli (*Capsicum annum* L.) Leaf Curl Complex and Yield in Jaffna District of Sri Lanka

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**Abstract** – A field study was conducted to evaluate the varietal performance of green Chilli (*Capsicum annum*) for Chilli leaf curl complex with different mulches and irrigation system from May to October 2016. Chilli is one of the most important cash crop grown in Sri Lanka. Generally Jaffna farmers get low yield (8- 10 ton / ha) from Chilli cultivation, mainly due to pest and diseases incidence. This research was carried out to study the effect of irrigation with different mulch material on leaf curl complex and the yield of green Chilli. The factors consisted of irrigation systems (sprinkler, drip and basin), varieties (Galkiriyagama, Super Hybrid and Vijaya hybrid) and mulch (No mulch, Neem leaves, Giliridicia leaves) in split plot design with three replicates. Results were analyzed by SAS package and the mean separation was done by Duncan method.(Probability 5 %). Plant height and canopy width were statistically not significant among irrigation, varieties and mulches. The difference in yield of chilli was statistically significant among varieties, mulches and irrigation systems. Higher yield was recorded in neem mulch under sprinkler irrigation system due to the low incidence of pest attack at 2nd harvesting (12 ton / ha). Therefore, sprinkler irrigation system with neem is more suitable for Super Hybrid chilli cultivation to reduce leaf curl complex and to obtain optimum yield.

**Keywords:** Leaf Curl Complex, Mulch, Irrigation system, Green Chilli

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## 1 INTRODUCTION

Chilli (*Capsicum annum* L.) belongs to the Solanaceae family, originated from South and Central America. Chilli is an indispensable spice due to its pungency, taste, appealing colour and flavour and has its unique place in the diet as a vegetable cum spice crop. The alkaloid 'capsaicin' present in placenta of the chilli fruit responsible for its pungency has diverse prophylactic and therapeutic uses in Allopathic and Ayurvedic medicine (Kanewardena, 2002) and directly scavenge various free radicals (Wierenga, 2005; Abbaset al., 2010; Ravinder et al, 1997) and has wide applications in the food, medicine and pharmaceutical industries. Chilli is a good source of vitamin C (ascorbic acid) used in food and beverage industries (Bosland and Votava, 2000).

It is one of the most important spice crops of the world and widely cultivated throughout the warm temperature in tropical and subtropical countries. A large extent under chili is cultivated in the dry zone of Sri Lanka. At present major Chilli growing districts are Anuradhapura, Moneragala, Ampara, Jaffna, Puttlam, Vavuniya, Kurunegala,

Hambantota and Mahaweli system. Department of Agriculture has recommended eight Chilli varieties up to now namely MI-1, MI-2, KA-2, Arunalu, MI-Hot, MI green, Galkiriyagama selection and the recently released varieties, MICH 3, MI Waraniya 1 and PC 1 (DOA, 2012).

The potential yield of these varieties are 10–12ton / ha. But the national average yields are as poor as 8–10 ton / ha (Department of Agriculture, 2015). Such low yields are mainly due to high incidences of pest and disease, moisture stress, the use of inferior quality of seeds, poor crop management and high input costs. Chilli Leaf Curl Complex (CLCC) is the major problem resulting in heavy yield losses up to 53%, especially during yala season. CLCC is caused by several factors (thrips, mites and viruses) of which thrips are the most important factor (Lewis, 1997). The Chilli crop can grow in field for about five months. The peak production is gained from the second picking. Early planting (before April) helps to get the high production due to low incidence of pest and disease. That means the second and third pickings are done before the severe attack of leaf curl complex (Kanewardena, 2002).

Irrigation method plays a major role in increasing the yield and enhancing cropping intensity. In North of Sri Lanka water scarcity and inefficient irrigation method are the major reasons for increasing cost of production. Therefore micro irrigation methods were proved to be an efficient method in saving water and reducing cost of production. Micro irrigation was also proved that it influence on increasing yield up to 20% to 30% and reduce the pest attack (Sadasivam and Senathraja, 2005). Most of the Jaffna farmers cultivate Chili under basin irrigation systems in small holding level (Kuepper, 2004). Even in small holding with well lift irrigation system water has been expensive because of the energy crisis (Demirbas, 2004).

Studies of different countries have confirmed that sprinkler irrigation is most effective for Chili cultivation as increasing yield, low incidence of pest and disease attack and low cost of cultivation (Shinde et al,1999; Wieranga, 2005). Further the Dry zone farmers are facing soil moisture lost by evaporation. Therefore different types of easily available mulches were introduced in this study to reduce evaporation losses and conserve soil moisture. Different countries studies confirmed that different mulches had tremendous effects on the number of pods yield (Abbas and Raza, 2010; Shinde et al, 1999; Ranvinde,et al 1997). Therefore the objective of this research is to study the impact of irrigation system and mulch on leaf curl complex and yield in Chili.

## **2 MATERIALS AND METHODS**

### **Site selection**

A Field experiment was carried out at the District Agricultural Training Centre, Thirunelvely during May end to October end 2016 in Calcic Red Yellow Latasol soil to study the impact of different mulches under different irrigation systems on varietal performance of green chilli.

### **Experimental design**

The experiment was conducted in split plot design with three replicates. For the design three types of irrigation systems namely sprinkler irrigation system (I1), Drip irrigation system (I2) and Basin irrigation system (I3) were used. There varieties, namely Galkiriyagame selection; Super hybrid and Vijaya hybrid were planted under two types of

mulches such as Neem (*Azadirachta indica*) and Gliciridia (*Gliricidia sepium*), and no mulch. Irrigation was included in the main plot. Subplot contained variety and mulches in the split-plot design. Twenty seven treatment combinations were tested in this experiment as shown in Table 1. Results were analyzed by SAS package (University version) and the mean separation was done by Duncan method (Probability 5 %).

**Table 1: Treatments and its descriptions**

Treatment	Treatment Code	Treatment Description
T1	I1VIM1	Sprinkler system, Galkiriyagame selection with no mulch
T2	I1V2M1	Sprinkler system, Super hybrid with no mulch
T3	I1V3M1	Sprinkler system, Vijaya hybrid with no mulch
T4	I1V1M2	Sprinkler system, Galkiriyagame selection with Neems leaves
T5	I1V2M2	Sprinkler system, Super hybrid with Neems leaves
T6	I1V3M2	Sprinkler system, Vijaya hybrid with Neems leaves
T7	I1V1M3-	Sprinkler system, Galkiriyagame selection with Gliciridia
T8	I1V2M3	Sprinkler system, Super hybrid with Gliciridia
T9	I1V3M3	Sprinkler system, Vijaya hybrid with Gliciridia
T10	I2V1M1	Drip system, Galkiriyagame selection with no mulch
T11	I2V2M1	Drip system, Super hybrid with no mulch
T12	I2V3M1	Drip system, Vijaya hybrid with no mulch
T13	I2V1M2	Drip system, Galkiriyagame selection with Neem leaves
T14	I2V2M2	Drip system, Super hybrid with Neem leaves
T15	I2V3M2	Drip system, Vijaya hybrid with Neem leaves
T16	I2V1M3	Drip system, Galkiriyagame selection with Gliciridia
T17	I2V2M3	Drip system, Super hybrid with Gliciridia
T18	I2V3M3	Drip system, Vijaya hybrid with Gliciridia
T19	I3VIM1	Basin system, Galkiriyagame selection with no mulch
T20	I3V2M1	Basin system, Super hybrid with no mulch
T21	I3V3M1	Basin system, Vijaya hybrid with no mulch
T22	I3V1M2	Basin system, Galkiriyagame selection with Neem leaves
T23	I3V2M2	Basin system, Super hybrid with Neem leaves
T24	I3V3M2	Basin system, Vijaya hybrid with Neem leaves
T25	I3VIM3	Basin System, Galkiriyagame selection with Gliciridia
T26	I3V2M3	Basin system, Super hybrid with Gliciridia
T27	I3V3M3	Basin system, Vijaya hybrid with Gliciridia

### Nursery management

Soil was sterilized by burning straw and beds (3 m×1 m×15 cm) were prepared. Seeds were directly sown at 10 cm between lines and 1 cm depth. A Thin layer of top soil was laid above the seed lines. After that, beds were treated with fungicide Homai (tetramethylthioperoxydicarbonic diamide)(6g / 5l H<sub>2</sub>O). Nursery beds were covered with dried banana leaves to prevent water loss. Then beds were treated with Elson (pyrethroids bifenthrin) to prevent the termite and ant problem. Nursery bed was protected from rain by covering with white polythene.

### Field preparation and layout

For proper establishment of seedlings, soil should be moist, friable, well aerated and weed free. Thus ploughing and two hoeing were done to obtain the fine tilled condition. Three blocks were made and one block was further divided in to 27 plots of 3m×3m size (Figure 1). Nine plots were covered by drip or basin or sprinkler irrigation system. One block included 675 hills and every block included sprinkler, drip and basin irrigation system. Each plot contained 9m<sup>2</sup> land areas with 25 hills.

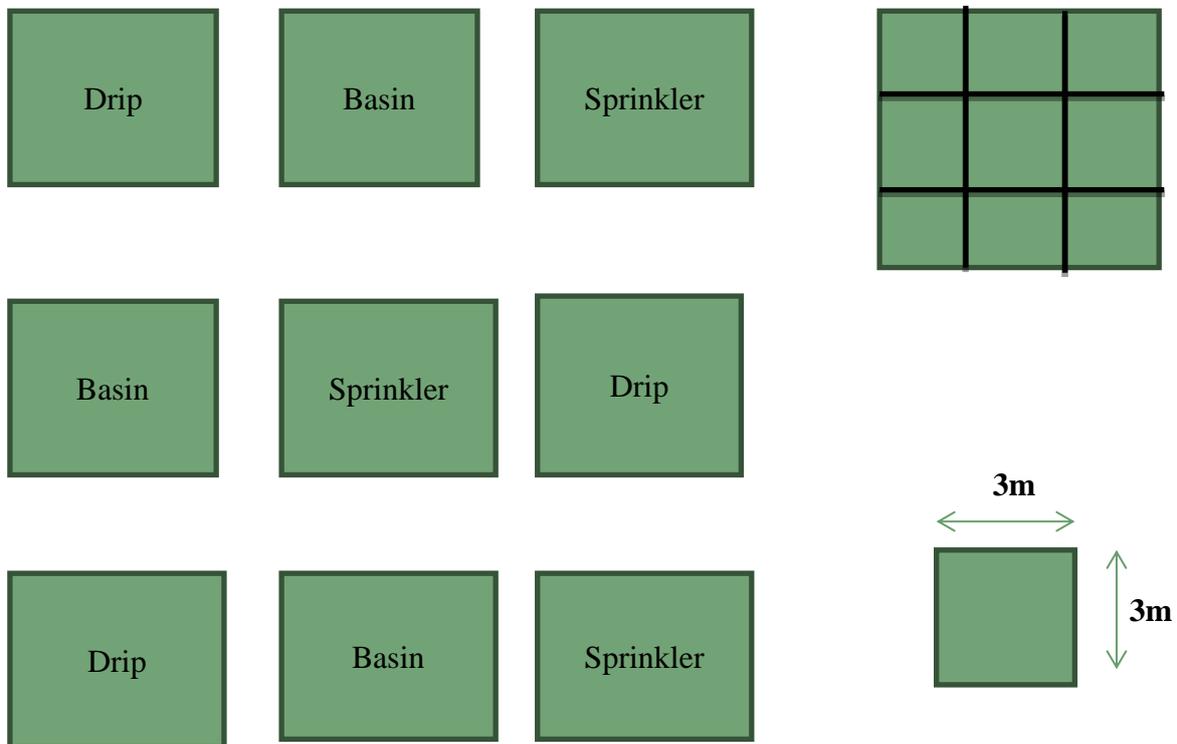


Figure 1: Lay out of the field experiment

### Field planting

The 35 day old seedlings were transplanted at 60 cm×60 cm (1pts / hill). Healthy, disease free and good quality seedlings were selected from nursery. Shade was provided for 2 to 3 days. Seedlings were irrigated immediately after transplanting by basin, drip and sprinkler irrigation methods. The gap filling was done after one week of transplanting.

## Cultural practices

### *Watering*

Watering was done 3 times / day after transplanting by hand up to 2 weeks. Then at initial stage irrigation was given at 3 days interval for 2 weeks to maintain continuous moisture to ensure better establishment of plants. After that, irrigation frequency was increased to 4-5 days for 2 weeks (basin irrigation system) and thereafter irrigation was done depending on the soil moisture. But sprinkler and drip were irrigated every day (Figure 2 and 3). Duration of application of Sprinkler is 30 minutes, drip irrigation is 1hr. The water requirement for the crop was assumed to be 900 mm for the whole period and it is 6-10mm/day. Based on the irrigation interval and the irrigation system this quantity of water is was calculated to provide equal quantity of total in all irrigation methods.



**Figure 2: Land preparation and layout**



**Figure 3: Irrigation after transplanting**

***Fertilizer application***

In this experiment, general recommendation was given to each crop by the Department of Agriculture. Well decomposed cattle manure was applied before planting at the rate of 20 t/ha (500g/hill) and mixed well with Basal application. Basal fertilizer application was applied to every nine plot which are having respective fertilizer notation. Irrigation was applied after application of fertilizer. During the growth period, four top dressings were done at different time with DOA recommendation as shown in Table 2.

**Table 2: Details of the fertilizer application**

	Urea(kg/plot)	TSP(kg/plot)	MOP(kg/plot)
Basal (2 DBP)	-	7.290	3.645
1 <sup>st</sup> TD (2 WAP)	4.738	-	-
2 <sup>nd</sup> TD (4 WAP)	6.196	-	-
3 <sup>rd</sup> TD (4 WAP)	6.196	-	3.645
4 <sup>th</sup> TD (12 WAP)	6.196	-	-

**DBP** - Days after planting      **WAP** -Weeks after planting

***Weed control***

Weeding is vital at the initial stage of the crop growth. Weeding was done regularly at every 25 days interval to control the weeds.

Watering, fertilizer application, weeding, pest and disease control were done according to the Department of Agriculture recommendations.

***Pest and disease control***

Leaf curl complex was observed during after 4 weeks of transplanting. Admire (Imidacloprid 70 WG (70% w/w)) was applied to control the vector. Anthracnose was observed in Chilli at the time of pod formation andDaconil (Active ingredient-Acibenzolar-S-methyl) was applied. Root rot was observed in Chilli during vegetative growth i.e. 2 weeks after transplanting. Homai (tetramethylthioperoxydicarbonic diamide) was applied to control this disease. Leaf eating caterpillar attack was observed during the pod formation period. Larvin (Thiodicarb 75% WP) was sprayed to prevent the leaf eating caterpillar.

***Maturity and harvesting***

Turning pod colour from green to dark green is the identification of maturity period. After maturity harvesting was done manually. First, three sample plants per treatment were marked by using colour ribbon and harvested separately for each treatment combination and each plot was harvested separately and pods were collected in gunny bag. First harvesting was done at two months after planting and 2<sup>nd</sup> and 3<sup>rd</sup> harvesting was done in two and half months and 3 months after planting.

## Observations and readings

Readings of growth parameters and yield attribute were recorded. During the cropping season the rainfall, average temperature and average humidity were monitored.

### *Plant height*

Randomly selected plants in each plot were used to measure the height. The plants were differentiated from others by using different colour ribbons. Plant height was measured in cm from the ground to the highest point of plant by using metal measuring tape. Plant height was measured in 4<sup>th</sup>, 5<sup>th</sup>, 6<sup>th</sup>, 7<sup>th</sup>, and 8<sup>th</sup> week after planting.

### *Canopy width*

The width of canopy was taken at two opposite directions by means of metal measuring tape. The average was recorded as width of canopy. Canopy width was measured in 4<sup>th</sup>, 5<sup>th</sup>, 6<sup>th</sup>, 7<sup>th</sup>, and 8<sup>th</sup> week after planting.

Pest and disease affected plants were counted for all the plots at 5<sup>th</sup>, 8<sup>th</sup>, and 12<sup>th</sup> weeks. Number of pods / plant was counted from selected plants in all treatment combinations at every harvest. Pods weight per plant from pods of sampled plants was measured by using balance. The average of those pod weight was recorded. Pod length was measured from pods of sampled plants by using foot ruler. The average of those pod length was recorded. The harvested fresh weight of green Chilli was measured in each treatment combinations.

## 3 RESULTS AND DISCUSSION

### 3.1 Growth parameters

#### *Plant height*

Maximum plant height (65.6cm) was obtained in super hybrid with neem mulches under drip irrigation system after 8<sup>th</sup> week of planting and minimum plant height (26.0 cm) was obtained in Galkiriyagama selection with neem mulch under basin irrigation system. The plant height increased in weekly intervals.

#### *Plant canopy width*

Plant canopy width of Chilli from 4<sup>th</sup> up to 8<sup>th</sup> week was not significantly different between block and between the variety and mulch. Figure 4 shows, graphically the maximum plant canopy width (65.6 cm) was obtained in super hybrid with neem mulches under drip irrigation system after 8<sup>th</sup> week of planting and minimum plant canopy width (26.0 cm) was obtained in Galkiriyagama selection with neem mulch under basin irrigation system.

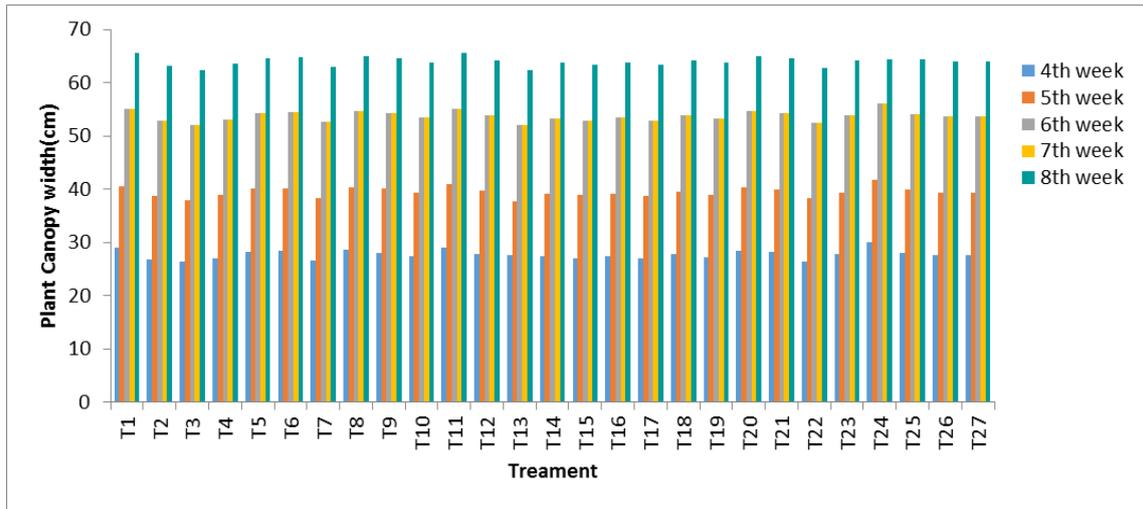


Figure 4: Mean performance of canopy width from 4<sup>th</sup> up to 8<sup>th</sup> week after planting

### 3.2 Incidence of Thrips for Chili Leaf Curl Complex attack

Chilli leaf curl complex (CLCC) incidence was significantly different between irrigation methods and was significantly differed between the variety and mulches (Figure 5). Thus it could be concluded that there is three way interaction between Irrigation, Mulch and Variety ( $I \times M \times V$ ). Incidence of CLCC attack was low at 5<sup>th</sup> weeks after transplanting. After that CLCC damage was increased due to the hot weather. Figure 6 shows, graphically the maximum CLCC was observed (10 plants) in Galkiriyagama selection with no mulch under basin irrigation system (T19) minimum was in Vijiya Hybrid with no mulch under sprinkler irrigation system at 12<sup>th</sup> weeks after planting and these treatments were statistically significant.

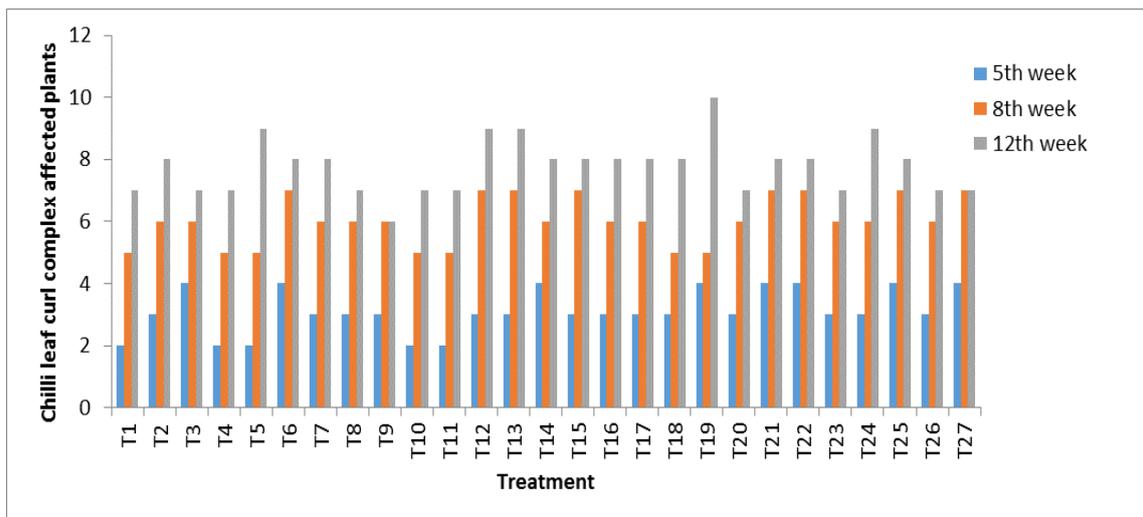
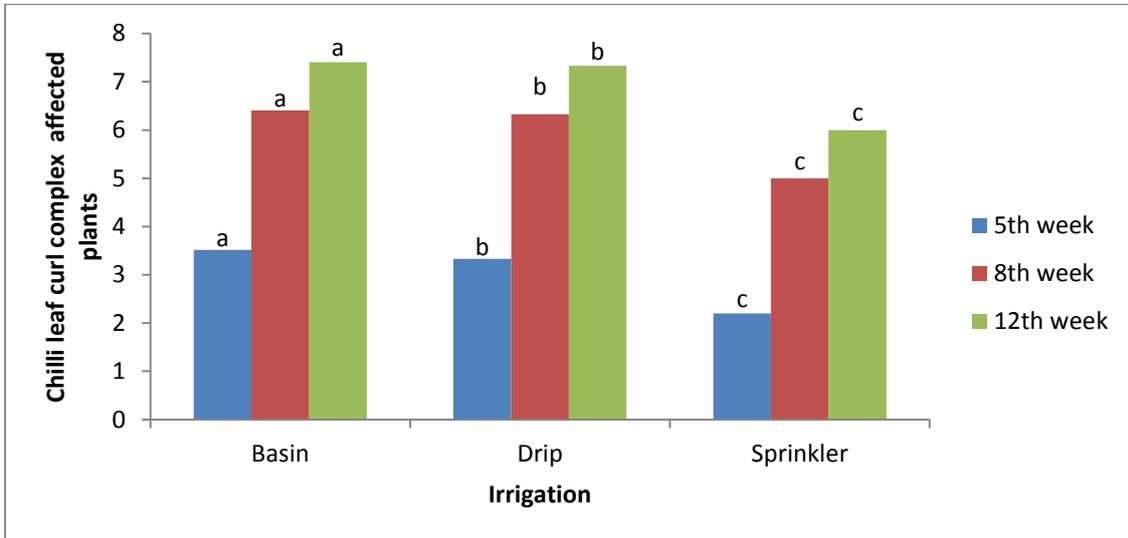


Figure 5: Chilli leaf curl complex in different treatment at 5<sup>th</sup>, 8<sup>th</sup> and 12<sup>th</sup> weeks after planting

*Chilli leaf curl complex attack among the irrigation*

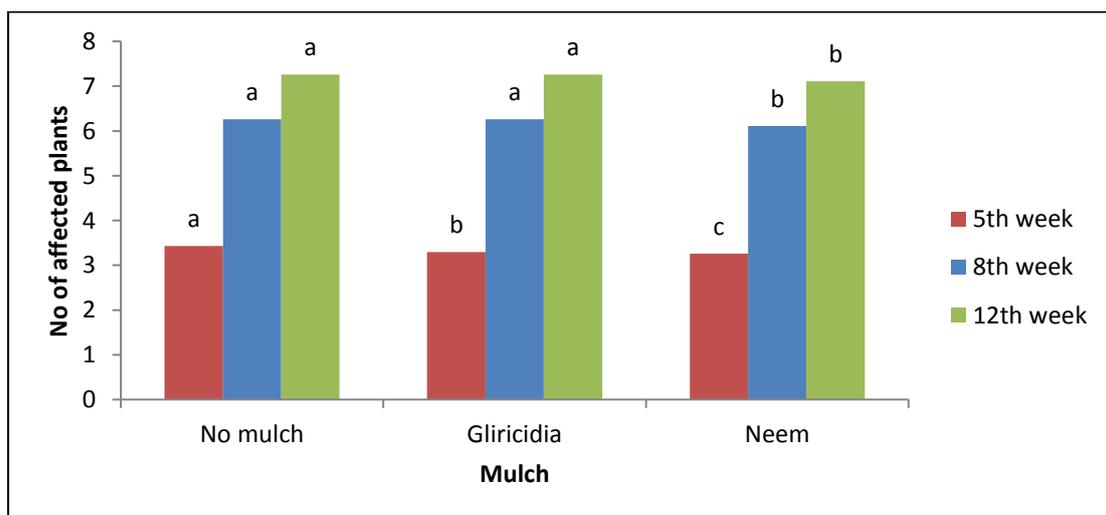
CLCC was significantly different among the irrigation systems (Figure 6). Incidence of CLCC was low under sprinkler irrigation at 5<sup>th</sup> week. This may be due to the flushing of insects and pests by sprinkler irrigation system. Further the sprinkler irrigation reduces the temperature within the plant canopy. But with weeks after that CLCC was increased due to the high air temperature of 34°C-35°C.



**Figure 6: Chilli leaf curl complex attack among the irrigation**  
(a, b and c are comparison within irrigation and among weeks)

*Chilli leaf curl complex attack among the mulches*

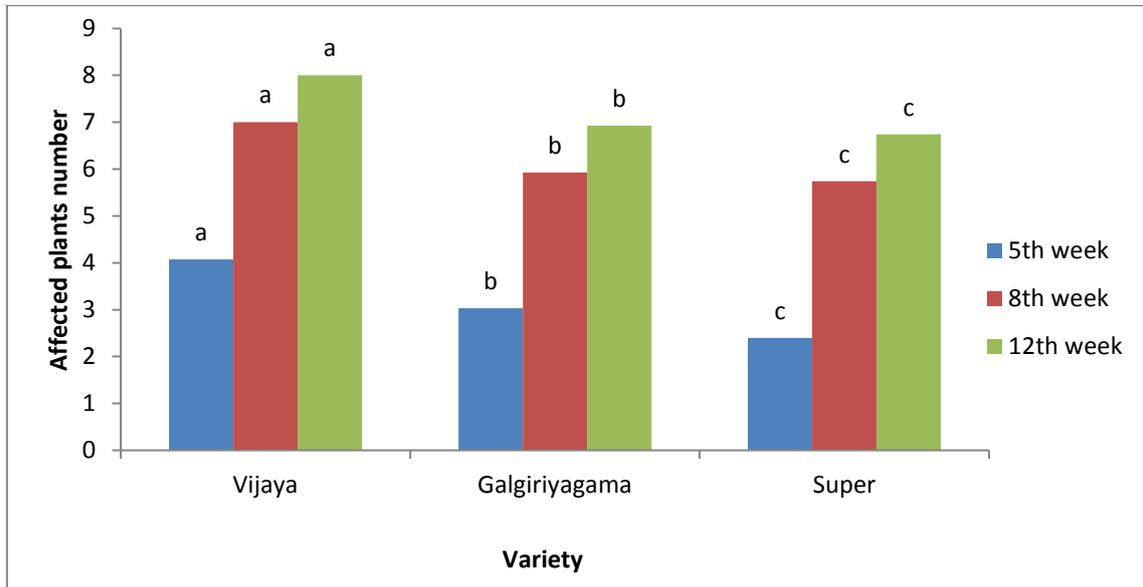
CLCC was significantly different among the mulch systems and lowest affected plants were observed in neem mulch at 5<sup>th</sup> week after transplanting. Highest was observed in no mulch system at 5<sup>th</sup>, 8<sup>th</sup> and 12<sup>th</sup> week after transplanting (Figure 7).



**Figure 7: CLCC attack among the mulch**  
(a, b and c are comparison within mulches and among weeks)

*Chilli leaf curl complex attack among the variety*

CLCC was significantly different among the variety. Minimum attack was observed in super hybrid and maximum attack was observed in Vijaya at 5<sup>th</sup>, 8<sup>th</sup> and 12<sup>th</sup> week after transplanting in shown in Figure 8. These results agree with the findings of Lewis (1997).



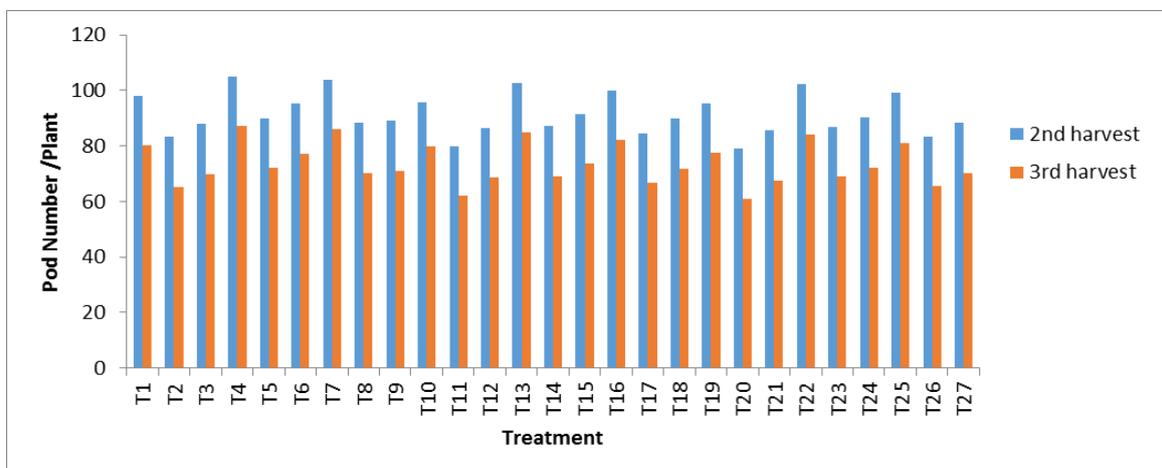
**Figure 8: CLCC attack among the varieties**

(a, b and c are comparison within varieties and among weeks)

**3.3 Yield parameters**

*Number of pods / plant*

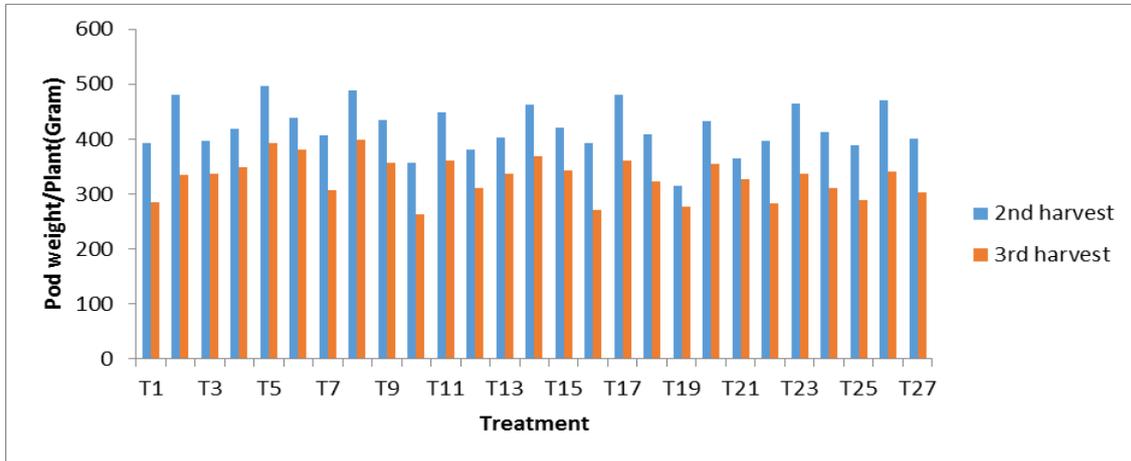
Number of pods per plant was significantly different between the irrigation and mulch and non-significant between block and variety. The highest pod number per plant (105) was obtained in Galkiriayagama selection with no mulch under sprinkler irrigation system at 2<sup>nd</sup> harvesting. Figure 9 shows yield was decreased from 2<sup>nd</sup> harvesting to 3<sup>rd</sup> harvesting.



**Figure 9: Number of pods / plant at 2<sup>nd</sup> and 3<sup>rd</sup> harvest**

**Pods weight / plant**

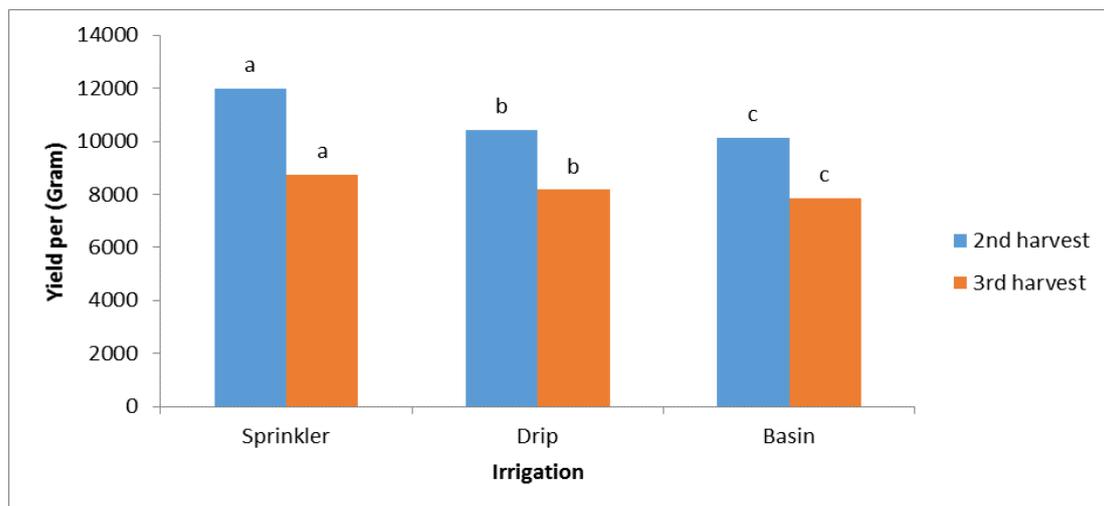
Pods weight per plant was not significantly different between the irrigation, variety and mulch non-significant between block. The highest pod weight per plant (496g) was obtained in super hybrid with neem under sprinkler irrigation system at 2<sup>nd</sup> harvesting. Figure 10 shows; yield was decreased from 2<sup>nd</sup> harvesting to 3<sup>rd</sup> harvesting. Higher pod weight was recorded under sprinkler irrigation system due to better microclimate.



**Figure 10: Pods weight / plant**

**Yield**

Chilli yield was significantly different between the irrigation, variety and mulch and non-significant between block. Figure 11 shows that yield was decreased from 2<sup>nd</sup> harvesting to 3<sup>rd</sup> harvesting. Highest (12 ton/ha) yield was recorded under sprinkler irrigation system due to the low incidence of pest attack and better microclimate (Maheswaran *et al*, 2017) and lower yield was recorded Galkiriyagama selection with no mulch under basin irrigation system (Figure 12 and 13). These findings agree with Shinde *et al*, (1999) and Wijerathana Banda, (1997) as they too found that low incidence of pest attack under sprinkler irrigation system.



**Figure 11: Yield (gram) of Chilli under different irrigation systems at 2<sup>nd</sup> and 3<sup>rd</sup> harvesting**

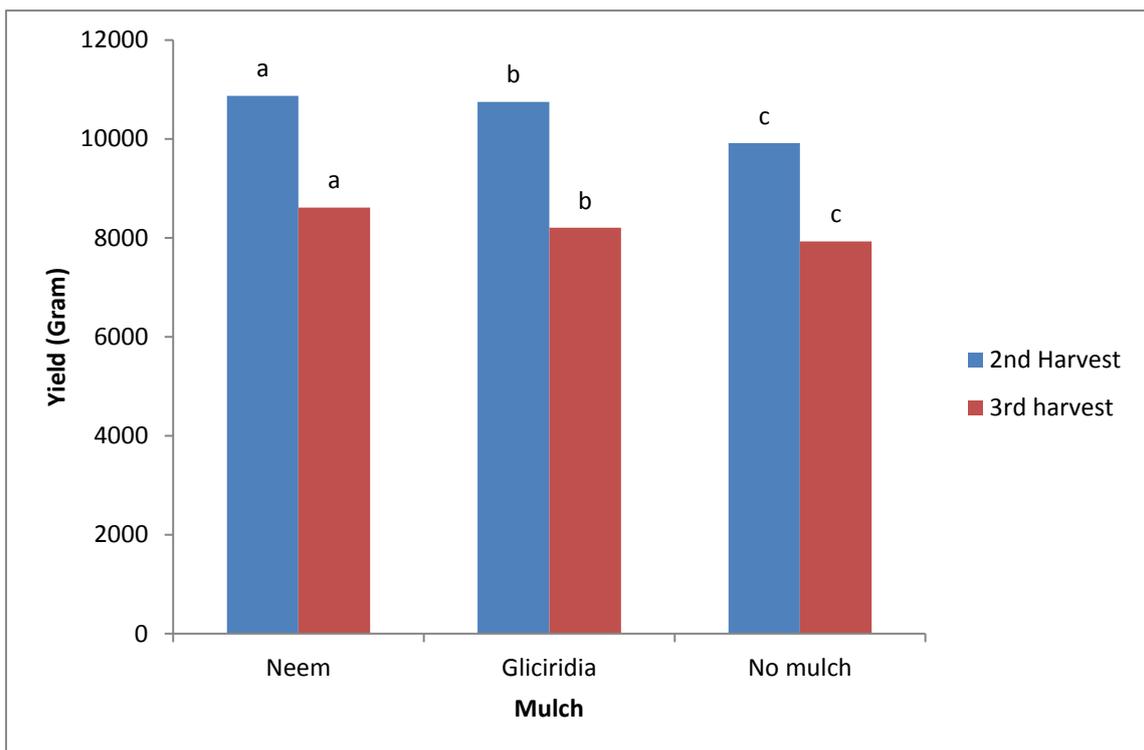


Figure 12: Yield (gram) of Chilli among different mulches

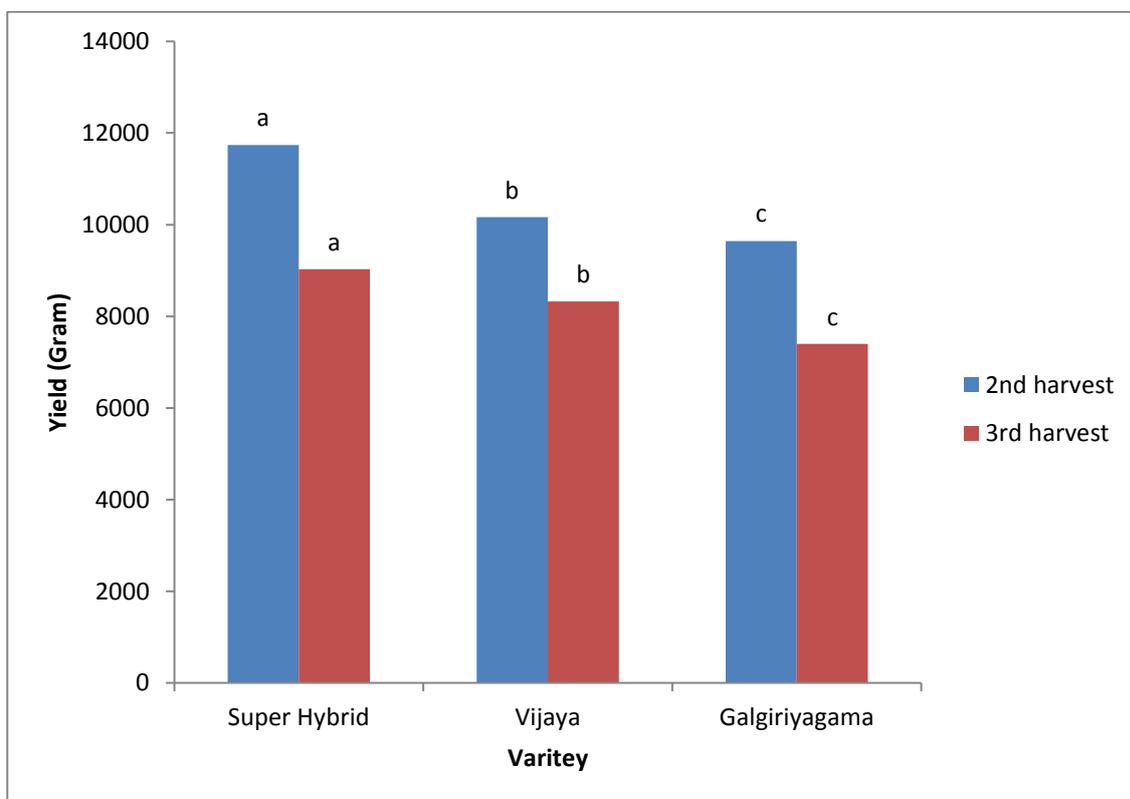


Figure 13: Yield of Chilli among varieties

#### 4 CONCLUSIONS AND RECOMMENDATIONS

Plant height of Chilli was not statistically significant with irrigation, variety and mulch. Plant canopy width of Chilli was not significantly different between varieties, irrigation and mulch in each week. Chilli Leaf Curl Complex was significantly different among the varieties and irrigation systems but not significant in mulch system. In sprinkler irrigation system and super hybrid variety plot is resistant to Chili Leaf Curl Complex. Weed population was significantly different with irrigation systems and different mulches over control.

The difference in yield of Chilli was statistically significant among varieties, irrigation systems and mulch. Higher yield was recorded under sprinkler irrigation system super hybrid variety with neem mulch 2nd harvesting (12 ton/ha). Peak production was obtained from the second harvesting of the same treatment.

Maximum yield was obtained in Super hybrid and minimum yield was obtained in Galkiriyagama selection variety at 2nd and 3rd harvesting. Sprinkler irrigation system is the best in Chilli cultivation with the use of neem mulch to reduce the thrip attack and Chilli leaf curl complex. Because, it will flush away the pests present in leaves. The micro climate of the plant and soil were changed respectively by the sprinkler irrigation and neem mulch system.

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