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PERFORMANCE EVALUATION OF SOLAR TRACKING BI-FOCAL COLLECTORS IN A SEMI ARID ENVIRONMENT, MAIDUGURI, NIGERIA.

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ABSTRACT

This study carried out the performance evaluation of solar bi-focal collector system under a semi-arid weather conditions in Maiduguri, Nigeria. The system has four distinct units, namely the solar collectors, the rotating shaft and framework supports, the mechanical clockwork pendulum system, and the water supply unit. Experiments were carried out during the raining and dry seasons in the years 2006 and 2007 using the bi-focal collectors for water heating, and from the results of the study, the maximum outlet water temperature achieved using the solar tracking bi-focal collector during the raining season was 76°C with maximum water temperatures rise of 41°C while the highest outlet water temperature measured during the dry season period was 78°C with maximum water temperature rise of 44°C. The solar tracking bi-focal collector system provides increased heating capacity and constitutes a simple and feasible concept which is appropriate for the use by people in rural areas of Nigeria and other developing country for heating purposes.

KEY WORDS: Solar, Bi-focal, Collector, Performance, Temperature.

INTRODUCTION

Exploitation of renewable energy resources has been in the forefront of campaign throughout the world for the supply of significant proportion of the world energy needs (Energetic Solutions, 2004), and solar radiation has been identified as the largest renewable resource on earth (Muller-Steinhagen, 2003). Solar energy can be applied in different ways and also many different methods for collecting the solar energy from incident radiation are available. One way of applying solar energy is through the use of solar thermal systems which could either be in the form of flat plate collectors or concentrating solar collectors among others. Concentrating collectors utilize optical system reflectors or refractors to increase the intensity of solar radiation on the energy absorbing surface. The optics for solar concentrating collectors is generally classified as either point focus or line focus systems. Three major solar - thermal technologies have been developed, the shape of reflecting surface on which sunlight is collected and concentrated characterizes each. These are the central receiver system, the parabolic trough, and the parabolic dish system (Cooper, 1972; Sayigh,1977; Magal, 1993; NREL, 2004).

In Nigeria, the status of renewable energy is available in literature (Garba et al., 1999; Energetic Solutions, 2004). Presently, the national energy supply is entirely dependent on fossil fuels and fire wood which are depleting fast, and the country has been feared may fall into fossil fuel trap in spite of the available renewable energy resources (Energetic Solution, 2004). These have made renewable energy to generate and attract attention in Nigeria, hence, the ongoing research efforts to utilize the renewable energy resources including solar energy resource. Adisa and Baba (2009) reviewed the solar cooking technology development in Nigeria while solar concentrators' development in Nigeria has been reported by Abdulrahim et al. (2010). This study carried out the performance evaluation of solar bi-focal collectors under a semi-arid weather conditions in Maiduguri, Nigeria.

MATERIALS AND METHODS

Materials

Solar bi-focal collectors developed by Abdulrahim (2008) was used in this study. The solar tracking bi- focal collector system is shown in figure 1. The system has four distinct units,

namely the solar collectors, the rotating shaft and framework supports, the mechanical clockwork pendulum system, and the water supply unit. Other materials used are water, measuring instruments such as Thermocouples (Model E 43593, Coley England), Mercury in glass Thermometesr (Fisherbrand, England), and Pyranometers (Model CM21, Kipp, and ZonenGroup, Holland).

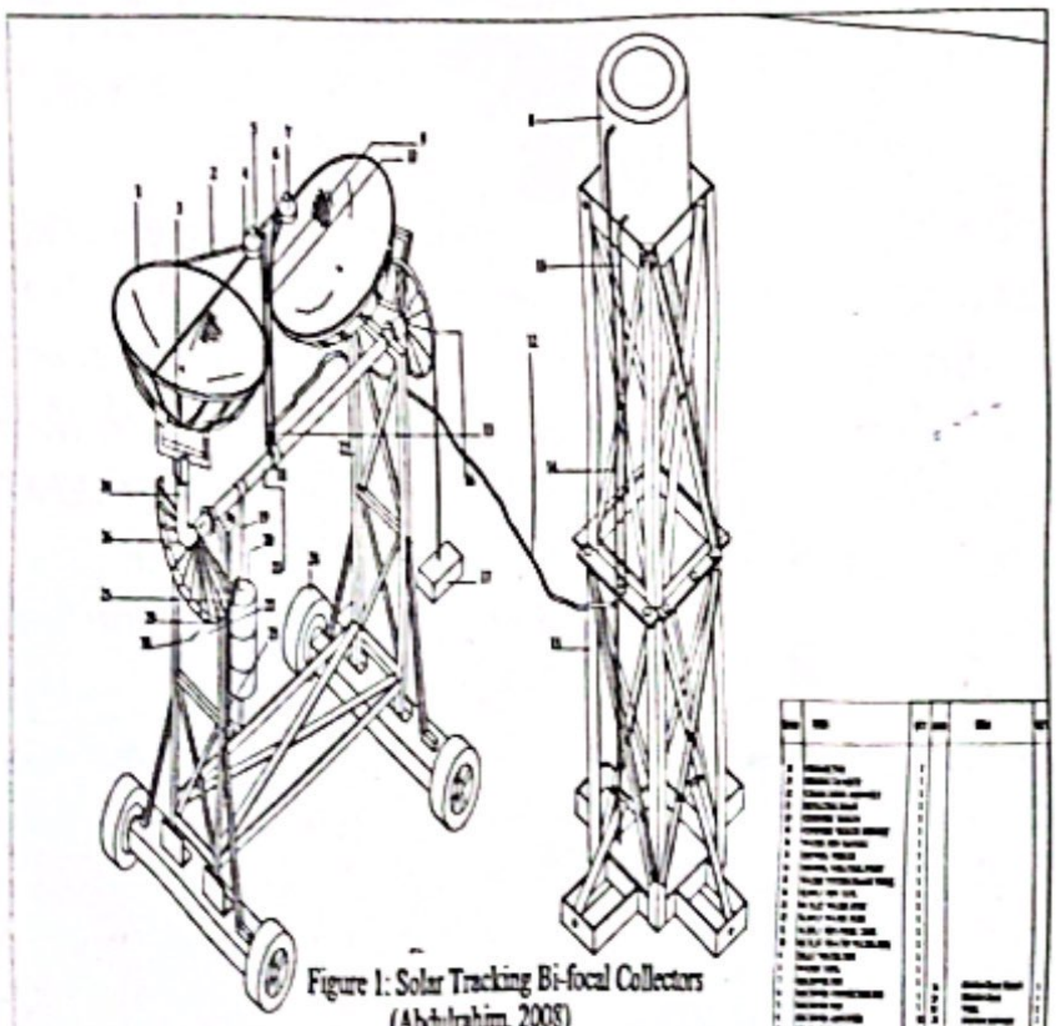


Figure 1: Solar Tracking Bi-focal Collectors (Abdulrahim, 2008)

METHOD

Principle of Operation

The operating modes of the Solar Tracking Bi-focal Collectors are shown in Plates 1 and 2. After system assembly by mounting all component parts of the Solar Tracking Bi-focal Collectors on a common base at the test site located within the University of Maiduguri, Nigeria Campus, the system is put into operation as follows: Daily in the morning, the system is manually oriented so as to face the morning sun in the east. The rotating support shaft is linked with the counterweight and the driving weight. When the driving weight is put into position, this positioning would make the collectors want to move back around their axis of rotation. The mechanical clockwork arrangement helps to decelerate the collectors' rotation to the required speed so that they can follow the sun accurately as it moves from east to west during the day.

Also, before the system operation, the water supply tank is filled with water while the valve on the tank [illegible] pipe remains closed. Water flows by gravity from the reservoir tank into the inlet pipe and metered into the circuit through a gate valve. Heat generated by the first receiver is absorbed by the water flowing inside the absorber pipe. The water entering the first receiver is heated and then flowed to the second absorber pipe in the second receiver through a connecting crossover pipe. In like manner, the incoming water is again heated further in the second receiver before being discharged into the outlet pipe of the second receiver.

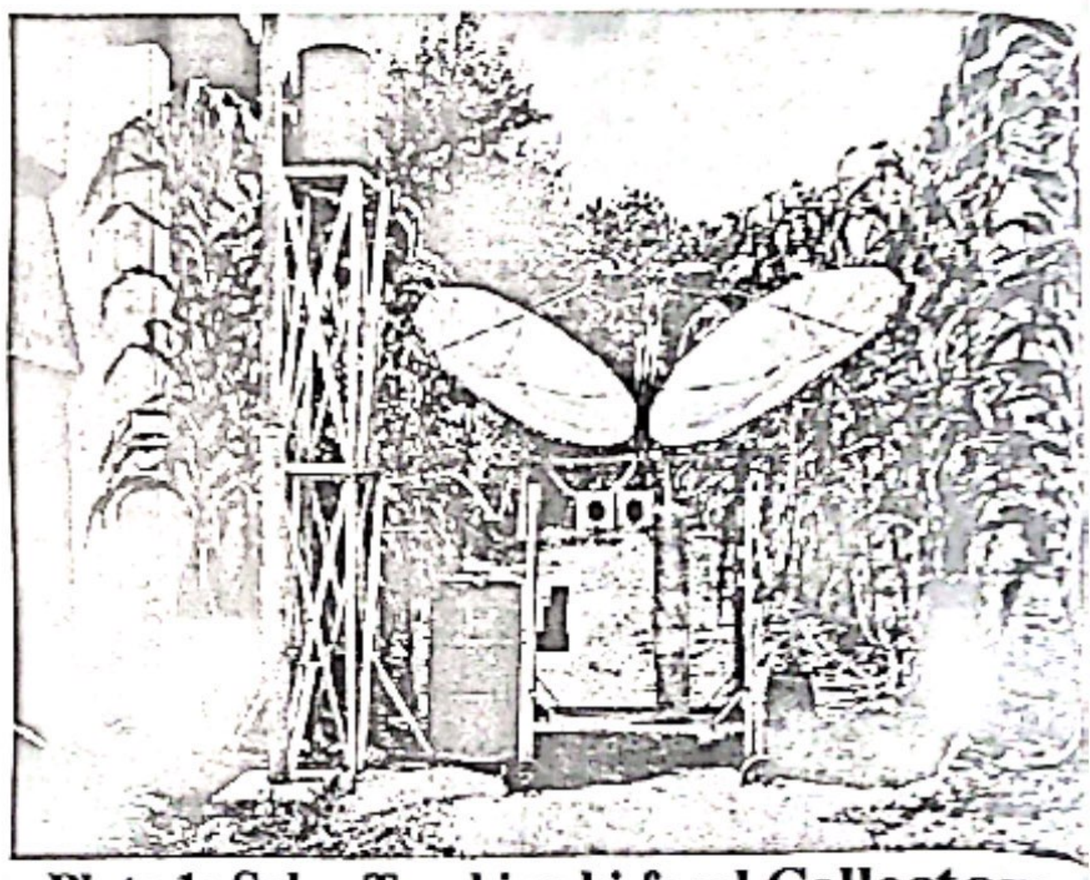


Plate 1: Solar Tracking bi-focal Collectors (Rain Season Testing)

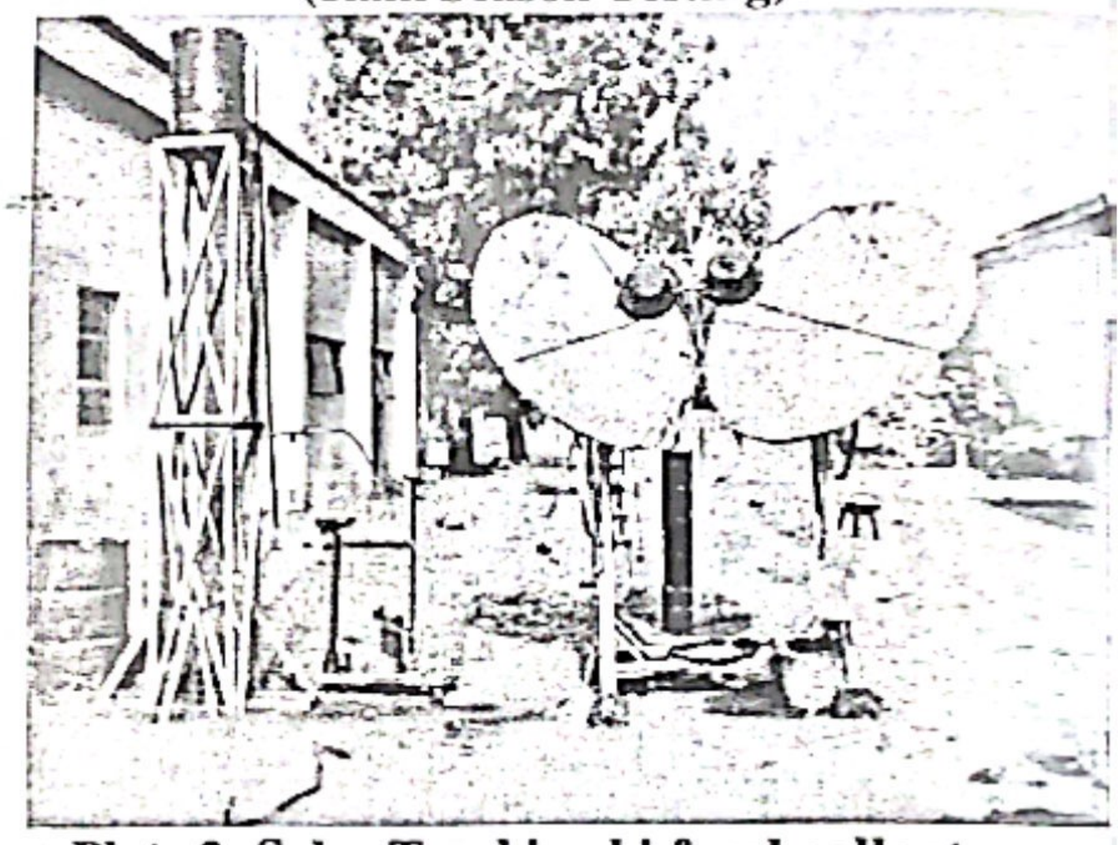


Plate 2: Solar Tracking bi-focal collectors (Dry Season Testing)

EXPERIMENTAL PROCEDURE

The performance of a solar tracking bi-focal collector system was assessed through water heating/boiling measurement in Maiduguri during the raining and dry seasons period. Maiduguri is located on latitude 11.85° North and longitude 13.08° East. The climate of the city is characterized by two distinct weather conditions namely the wet and dry seasons. The wet season begins in the late May or early June and last up till September or early October, while the dry season begins from late September or early

October to early June (FAO, 1984; Gisilanbe, 1995). The solar tracking bi-focal collector system was placed in the sun at a site within the Faculty of Engineering Teaching Workshop, University of Maiduguri, Nigeria on the days of the experiments. The inlet and outlet water temperatures in the first collector were measured using thermocouples (Model E43593, Coley England). The outlet water temperature from the second collector and the ambient temperatures were measured using Mercury in glass thermometers (Fisherbrand, England). The direct beam radiations during the period of the experiments were found by using two Pyranometers (Model CM21, Kipp and Zonen Group, Holland). One of the pyranometers was fixed with a shadow ring in order to measure the diffuse solar radiation component while the second one measured the global solar radiation. The difference of the two values gives the value for direct beam radiation. The pyranometers were connected to digital multi-meters (ALDA Model: DT830B, 8300 series) that serve as the read out equipments for the pyranometers. The readings of measured values were taken on thirty minutes interval in some days and one hour interval for some other days.

With this mode of arrangement, experiments were carried out during the raining and dry seasons in the years 2006 and 2007. Experimentation results on the following typical days of September 16 and 17, 2006, September 16 and 17, 2007, and October 16 and 17, 2007 are reported in this study for the raining season period. And experimentation results on typical day conditions of February 13 and 14, November, 16 and 17, 200, and December 13 and14, 2007 are reported in this study for the dry season period.

RESULTS AND DISCUSSION

The variation of measured solar tracking bi-focal collector system's performance parameters such as the inlet water temperatures and the outlet water temperatures with time of the day are presented in figures 2a, 2b, 3a, 3b, 4a, 4b, 5a, and 5b for both the Dry and Raining seasons, while the prevailing atmospheric conditions with regards to the Ambient temperatures and the Direct Beam Solar radiation are shown in figures 6a, 6b, 7a, 7b, 8a, 8b and 9. During the dry season, the Inlet water temperature varies from the lowest value of 25°C to a maximum value of 44°C and outlet water temperatures range from 44°C to 78°C with maximum water temperature rise of 44°C during the test period. While the Maximum Ambient Temperature and Beam Solar Radiation were found to be 41°C and 854.3 W/m^2 respectively. In the raining season tests, the Inlet water temperature varies from the lowest value of 32°C to a maximum value of 39°C and outlet water temperatures range from 57°C to 76°C with maximum water temperature rise of 41°C during the test period. While the Maximum Ambient Temperature and Beam Solar Radiation were found to be 36°C and 890.51 W/m^2 respectively.

The performance obtained may not be unconnected with the seasons of the year. The raining season period is usually attributed with fluctuation of direct beam radiation due to intermittent cloud formation, and cloud cover was observed for some hours in some days during the test carried out in the raining season. Due to this the solar collector system was not receiving enough solar radiation required to sustained high temperature. Since the amount of direct sunlight was a big factor in the operation of solar system, the Collector Outlet Water temperatures measured that ranges from 57°C to 76°C could be justified. The Dry season test period is also significant because of the peculiar characteristics of the prevailing weather conditions especially the harmattan dust particles during December, January and February, and the clear weather of the transition period between the dry and the wet seasons that is common of March, April and May. The lowest Collector Outlet Water Temperature of 44°C was recorded during the harmattan period in December. During clear days within period of testing, the solar collector system was able to concentrate the available sunlight and use it to sustain a reasonable temperature in the absorber tubes that heat the flowing water. This could be a justification for highest temperature of 78°C obtained in March.

Previous works on solar concentrated collectors in this part of the globe were the single dish type solar collectors with manually tracking systems (Pelemo, 2000; Dahiru et al., 2007). The present study has demonstrated the potential of solar dish systems to be linked together in order increase generating capacity, and the application of mechanical clockwork system as an appropriate automatic tracking devices for the solar bi-focal collector system. Though, the results obtained is quite a fair performance, the

solar tracking bi-focal collector system has the potential for further improvement and modification through which it would be able to provide a sustainable advantage over other sources of heating system that have negative impact on the environment.

CONCLUSION

From the results of this study, the maximum outlet water temperature achieved using the solar tracking bi-focal collector during the raining season was 76°C with maximum water temperatures rise of 41°C while the highest outlet water temperature measured during the dry season period was 78°C with maximum water temperature rise of 44°C during the period under study. The solar tracking bi-focal collector system provides increased heating capacity and constitutes a simple and feasible concept which is appropriate for the use by people in rural areas of Nigeria and other developing country for heating purposes. Moreover, appropriate modification and improvement will put the solar tracking bi-focal collector system in a position of potential application in steam production for possible power generation.

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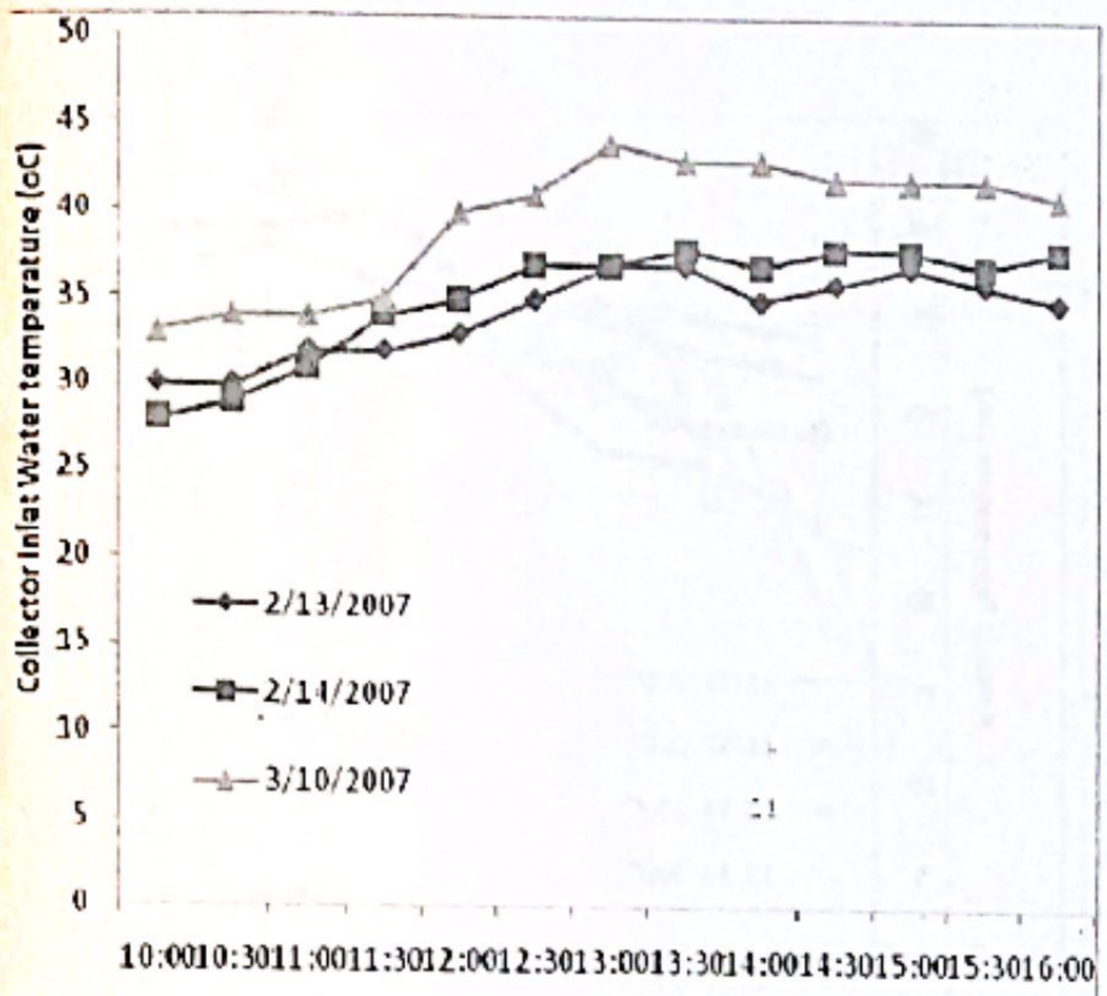


Figure 2a: Variation of Collctor Inlet Water Temperature Vs Time of the Day (Dry season)

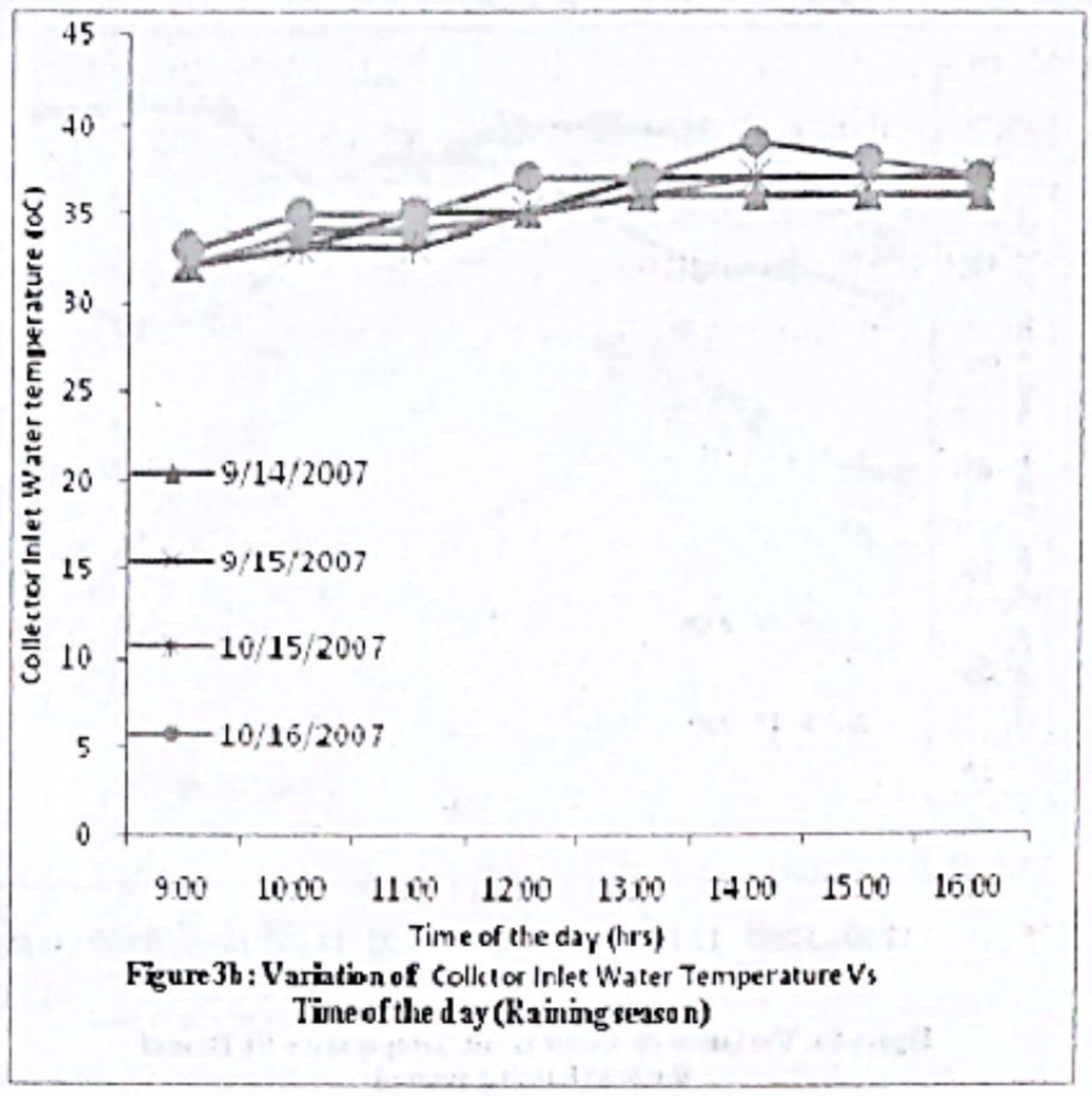


Figure 3b: Variation of Collctor Inlet Water Temperature Vs Time of the day (Raining season)

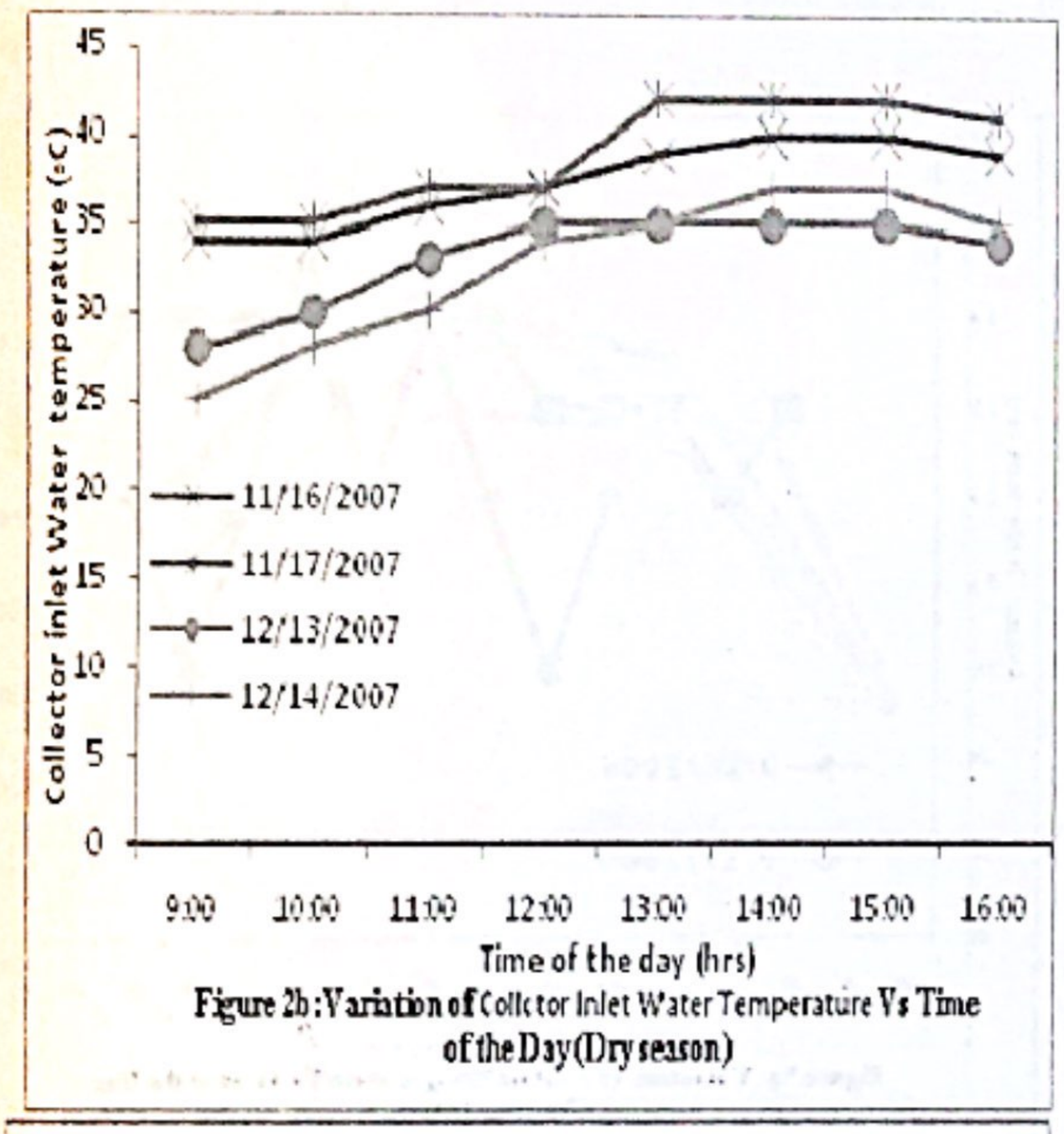


Figure 2b: Variation of Collctor Inlet Water Temperature Vs Time of the Day (Dry season)

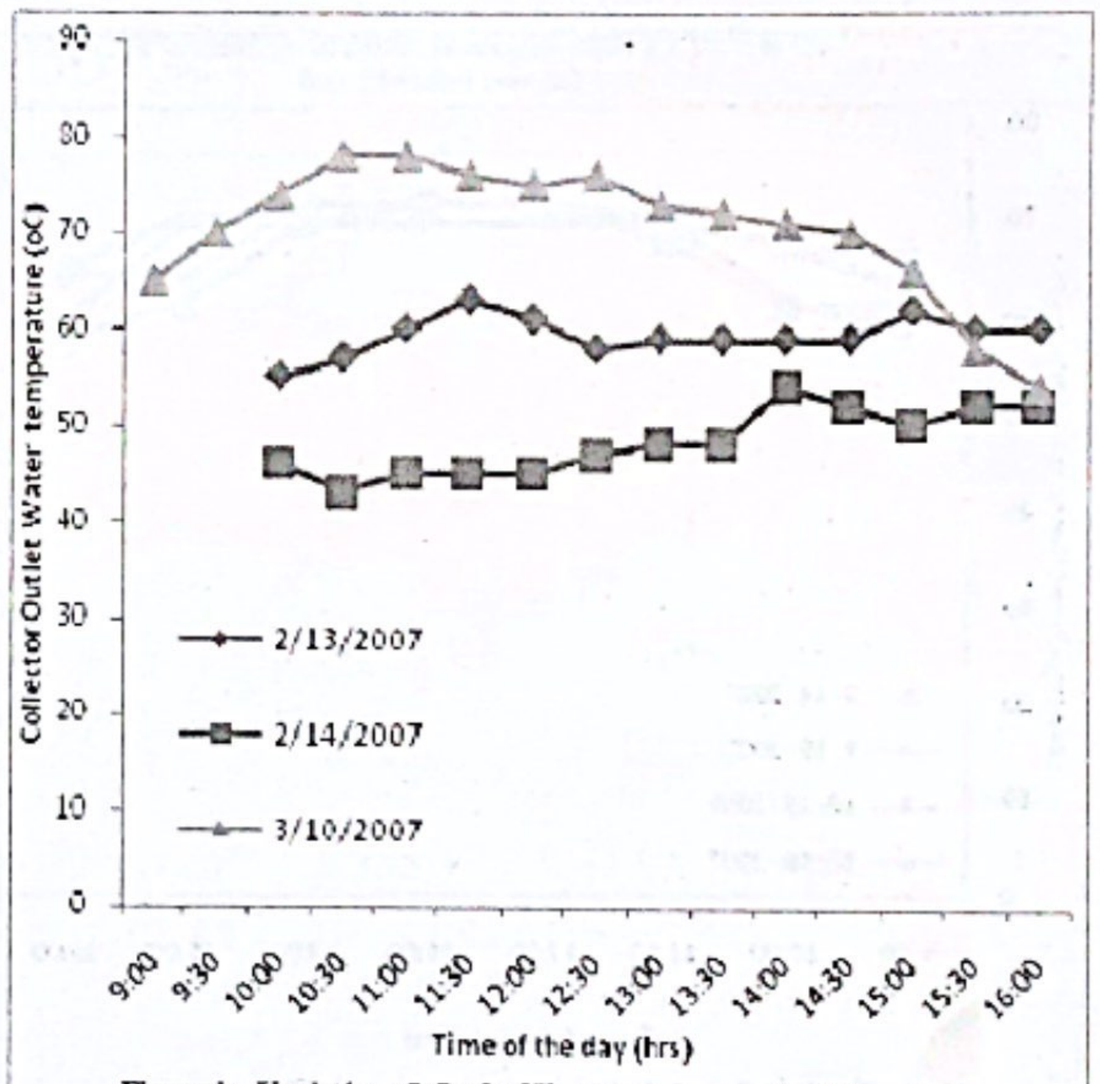


Figure 4a: Variation of Outlet Water temperature Vs Time of the Day (Dry season)

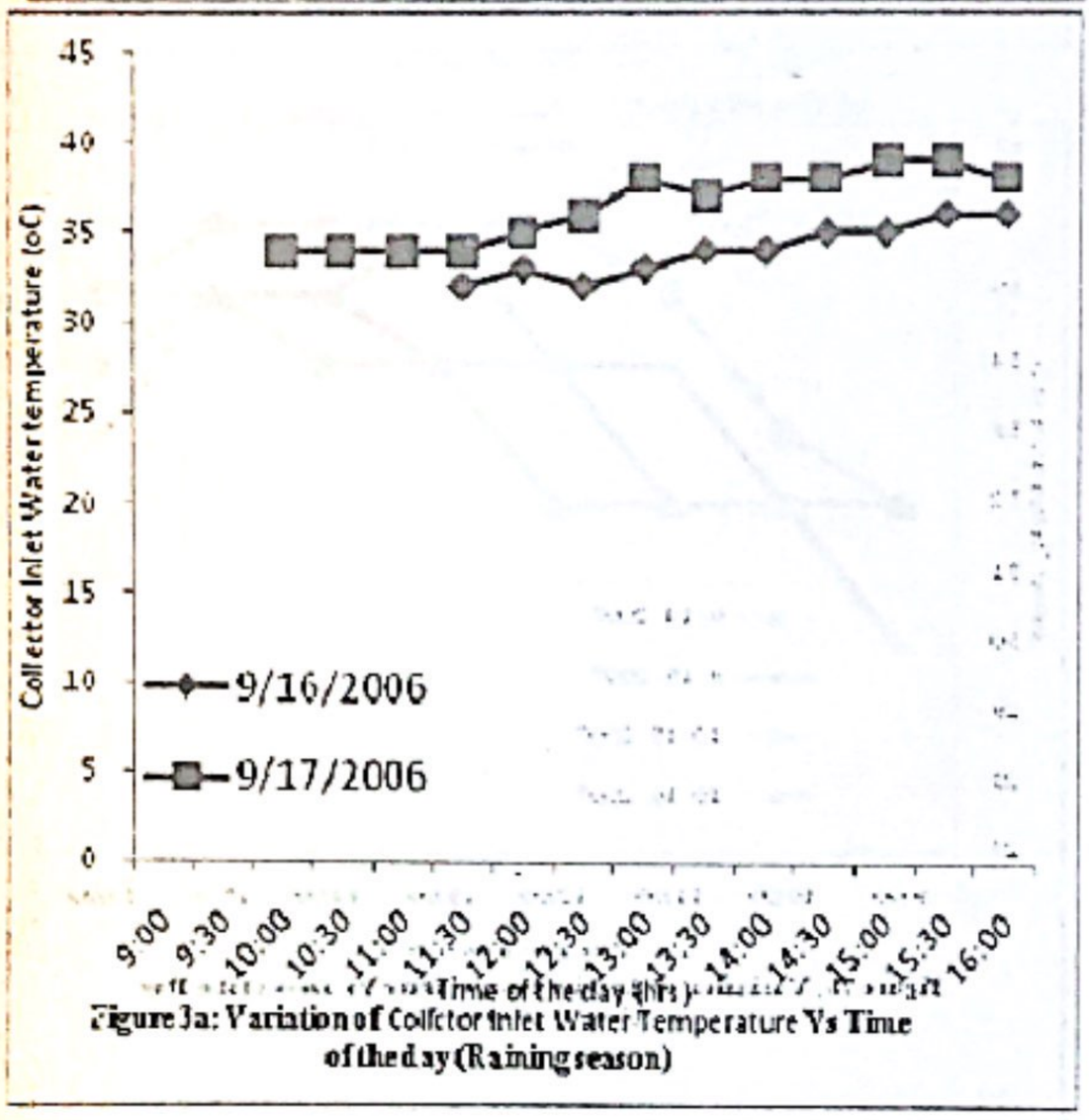
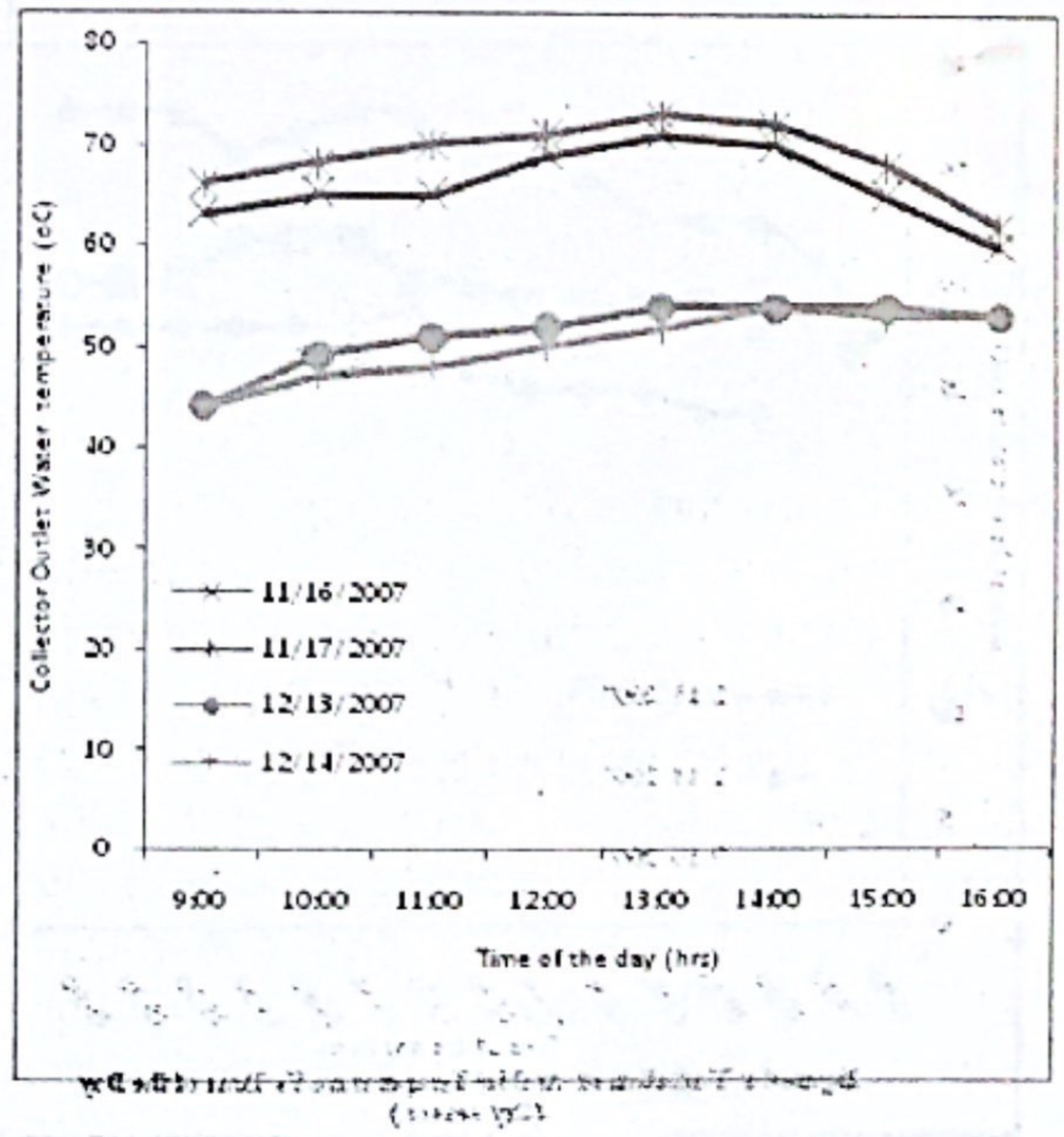


Figure 3a: Variation of Collctor Inlet Water Temperature Vs Time of the day (Raining season)



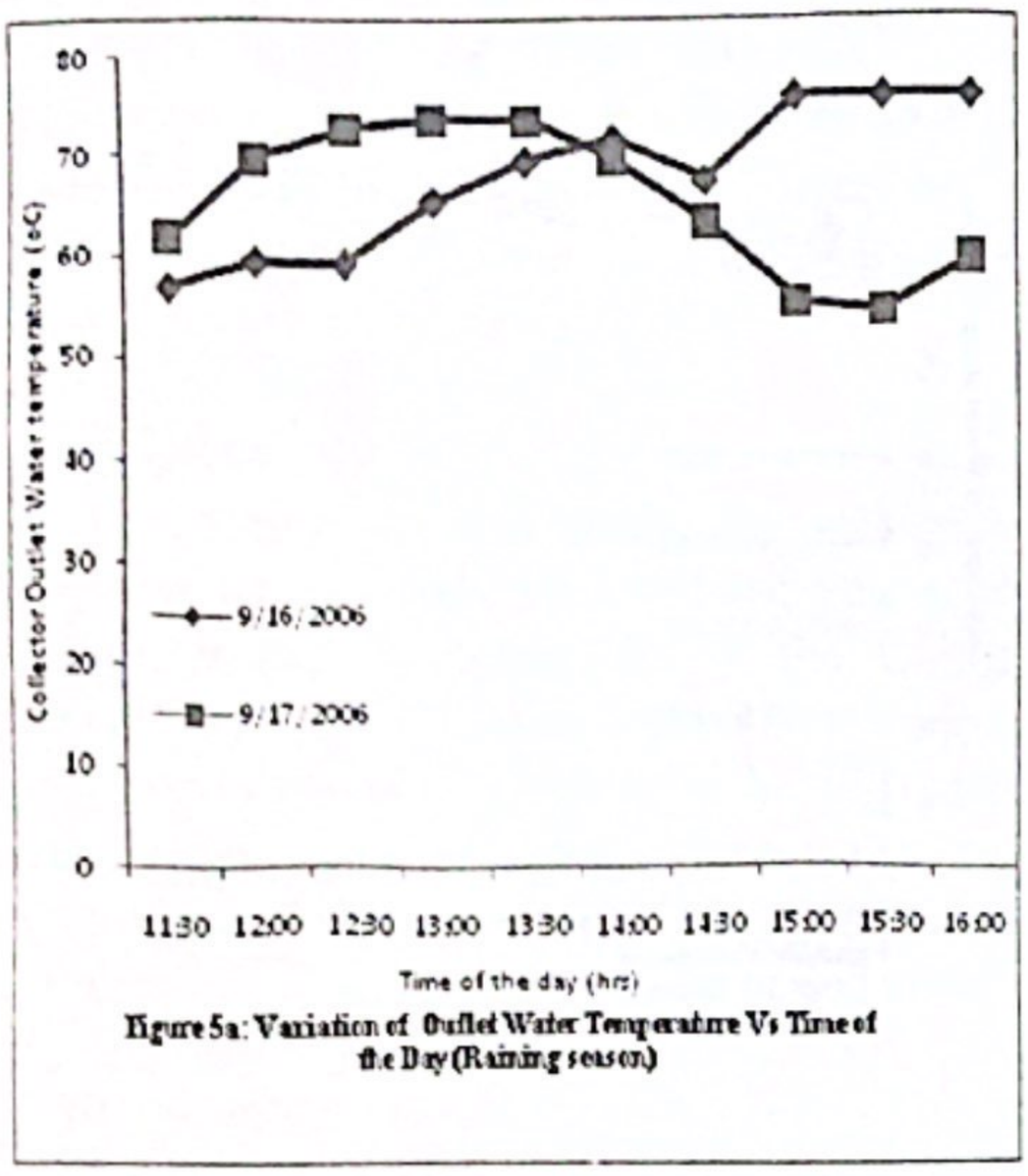


Figure 5a: Variation of Outlet Water Temperature Vs Time of the Day (Raining season)

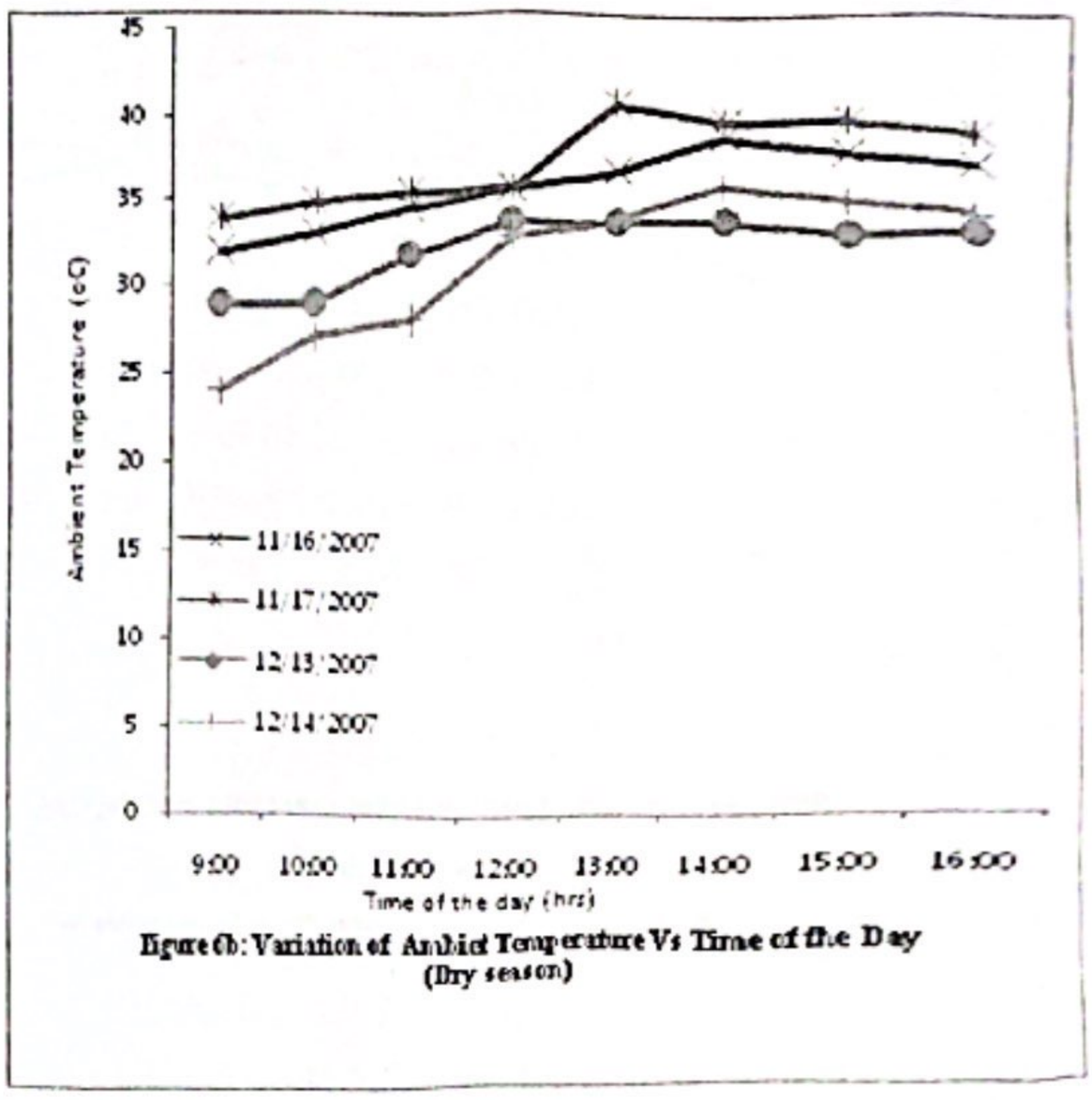


Figure 6b: Variation of Ambient Temperature Vs Time of the Day (Dry season)

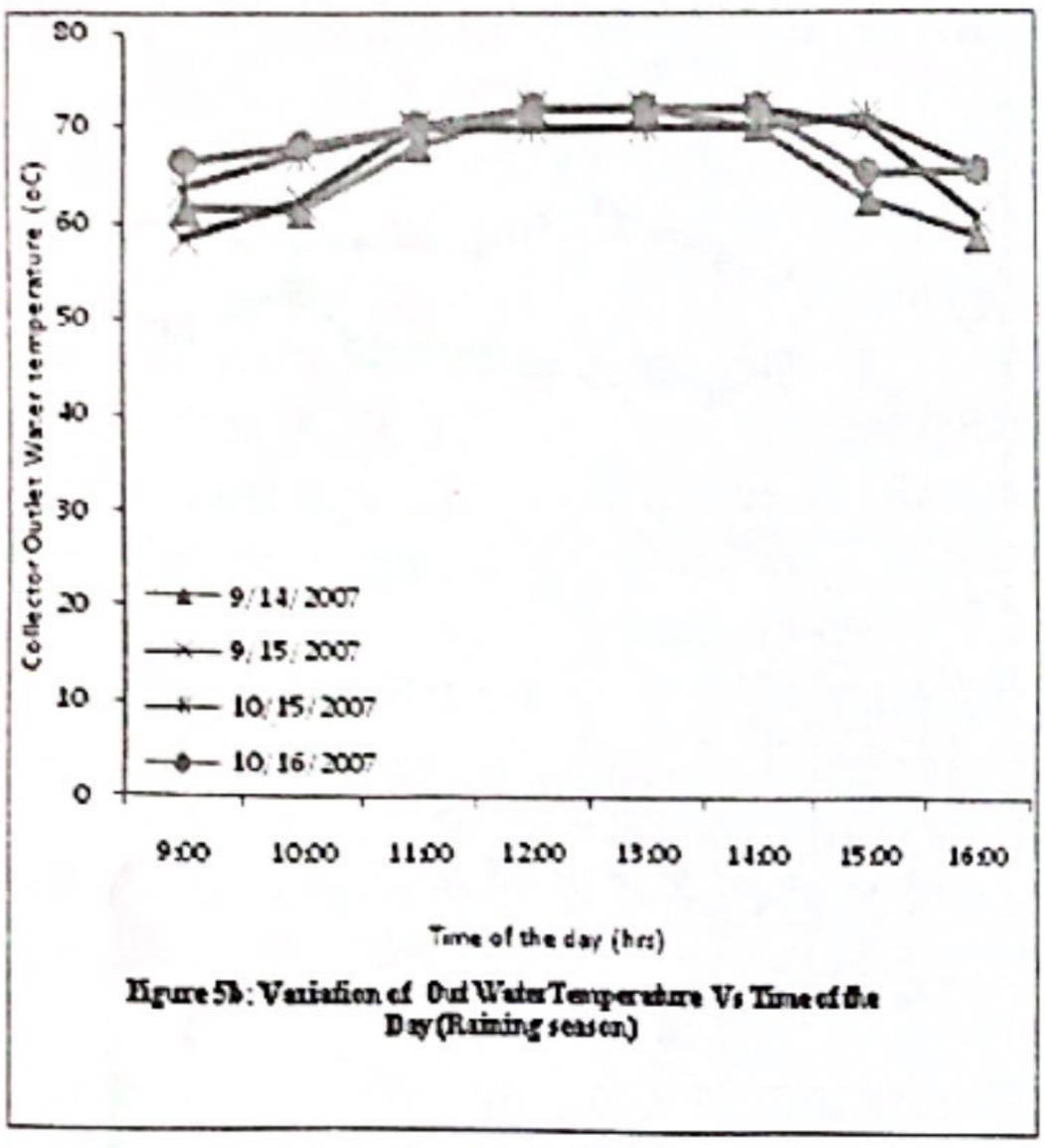


Figure 5b: Variation of Out Water Temperature Vs Time of the Day (Raining season)

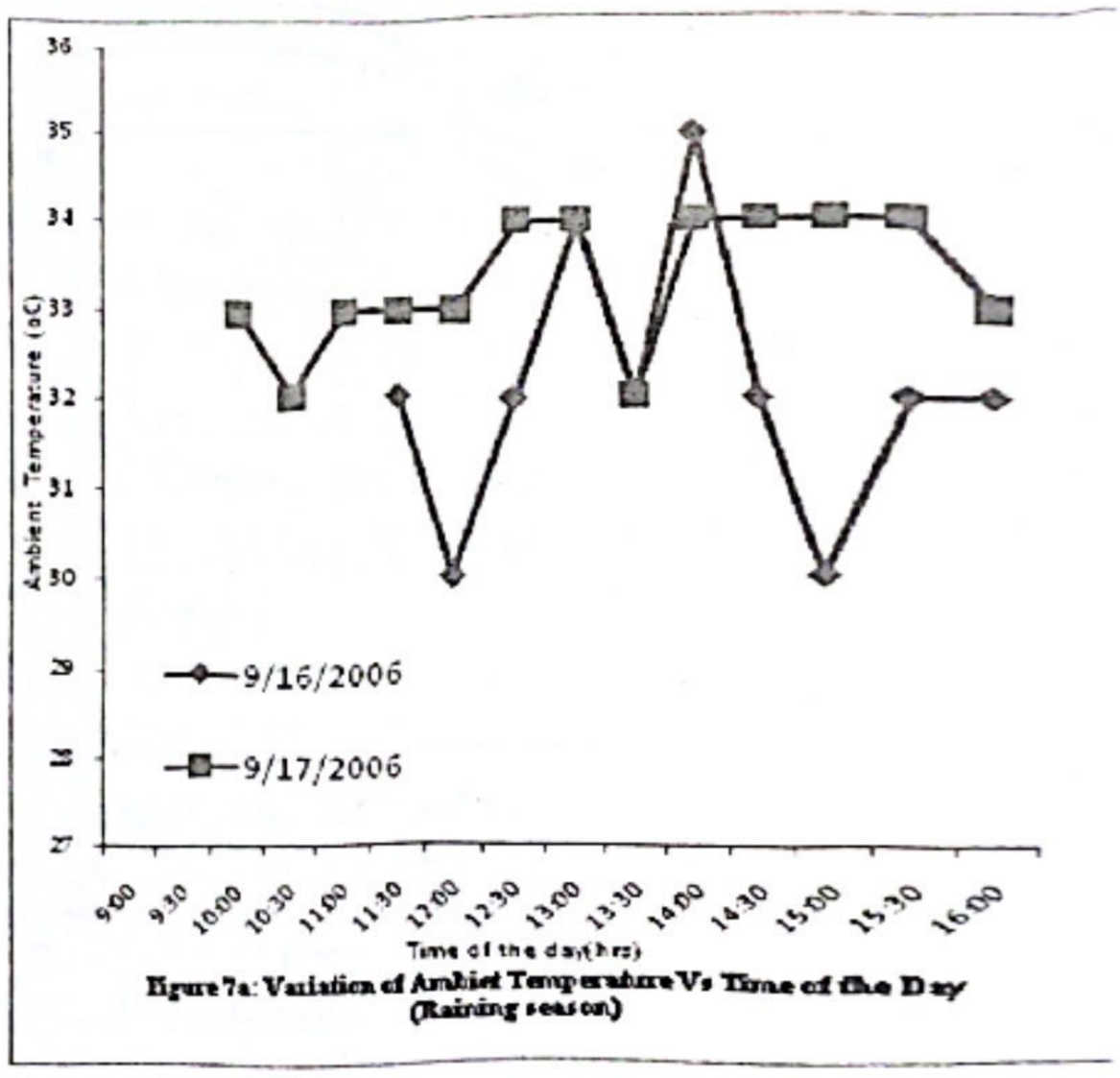


Figure 7a: Variation of Ambient Temperature Vs Time of the Day (Raining season)

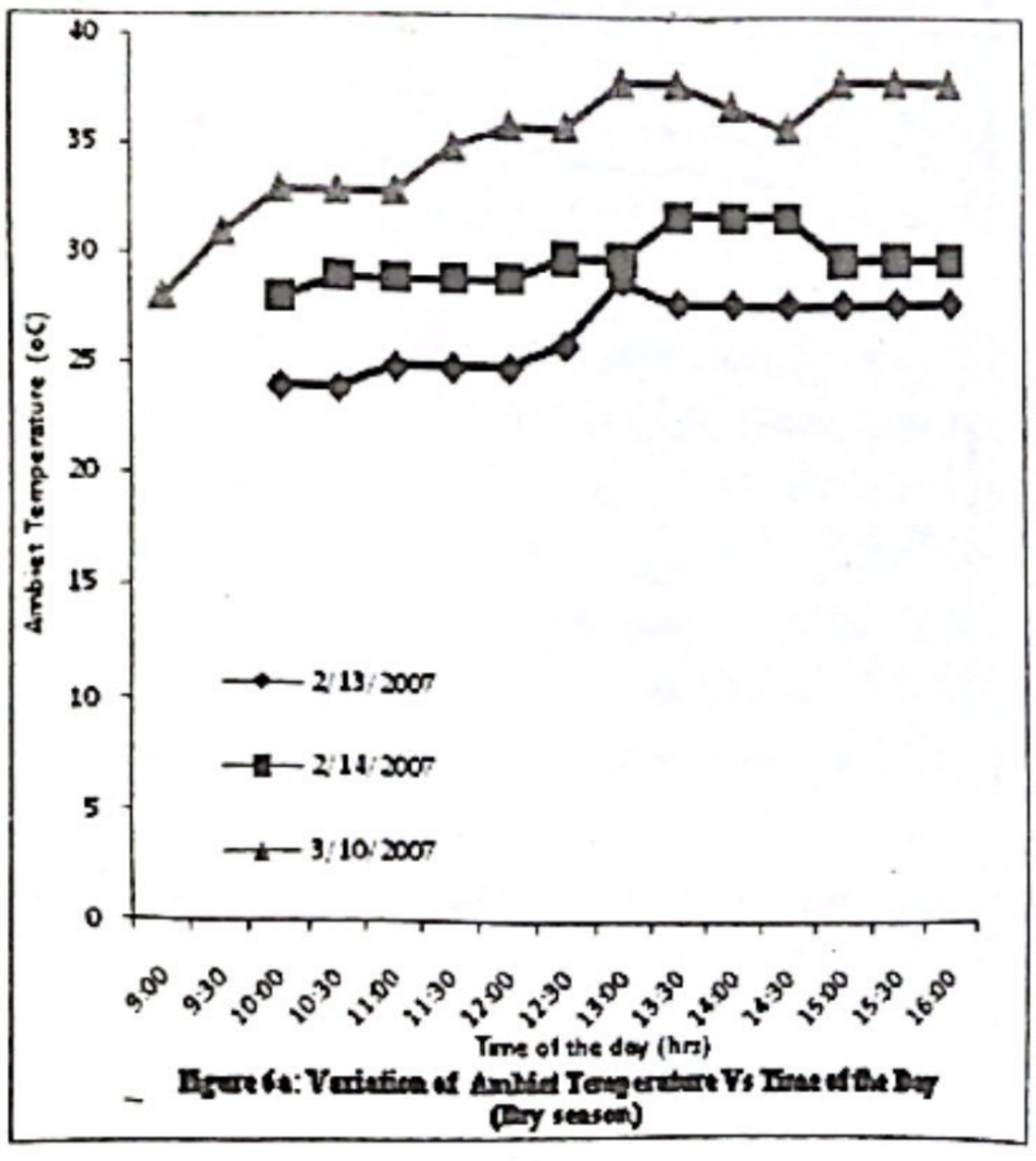


Figure 6a: Variation of Ambient Temperature Vs Time of the Day (Dry season)

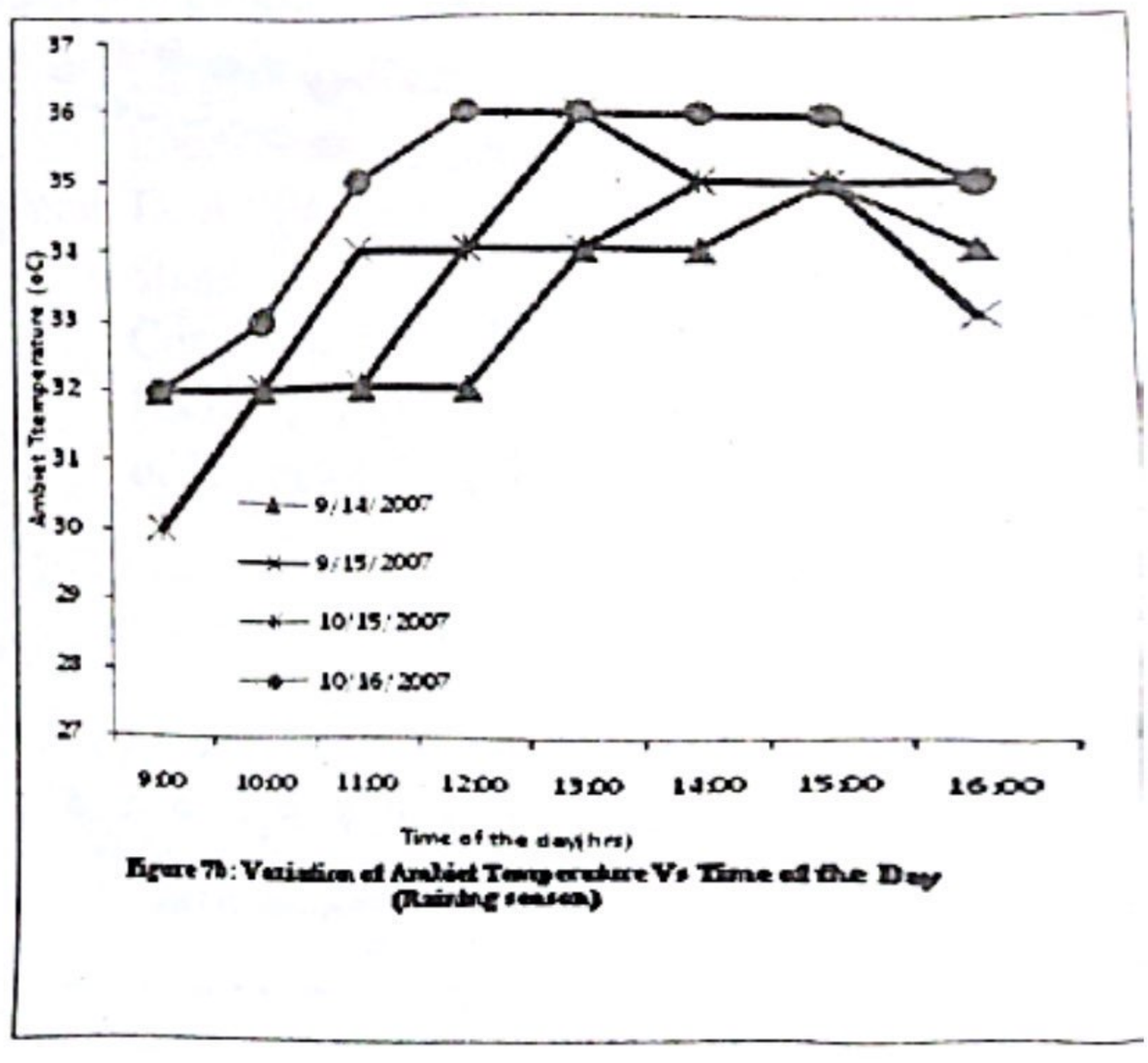


Figure 7b: Variation of Ambient Temperature Vs Time of the Day (Raining season)

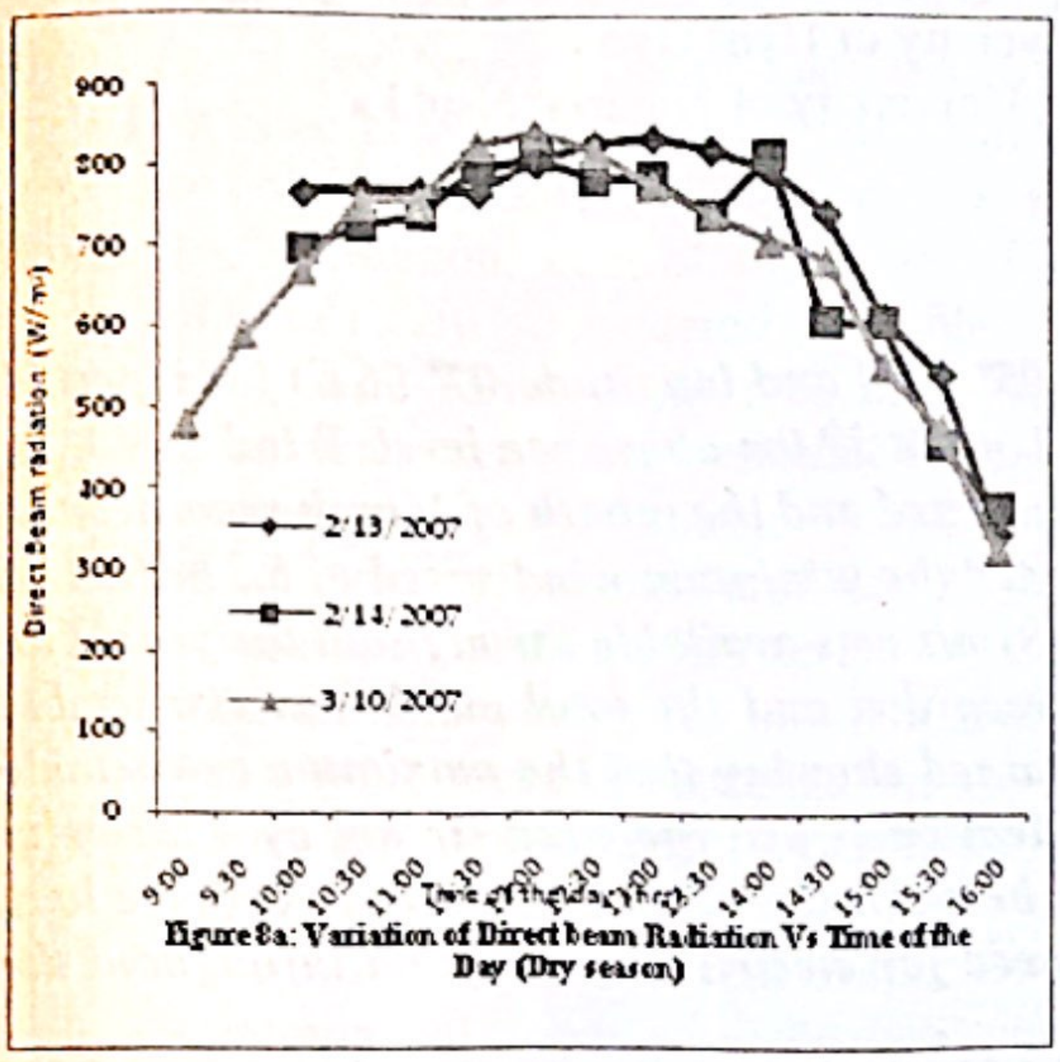


Figure 8a: Variation of Direct beam Radiation Vs Time of the Day (Dry season)

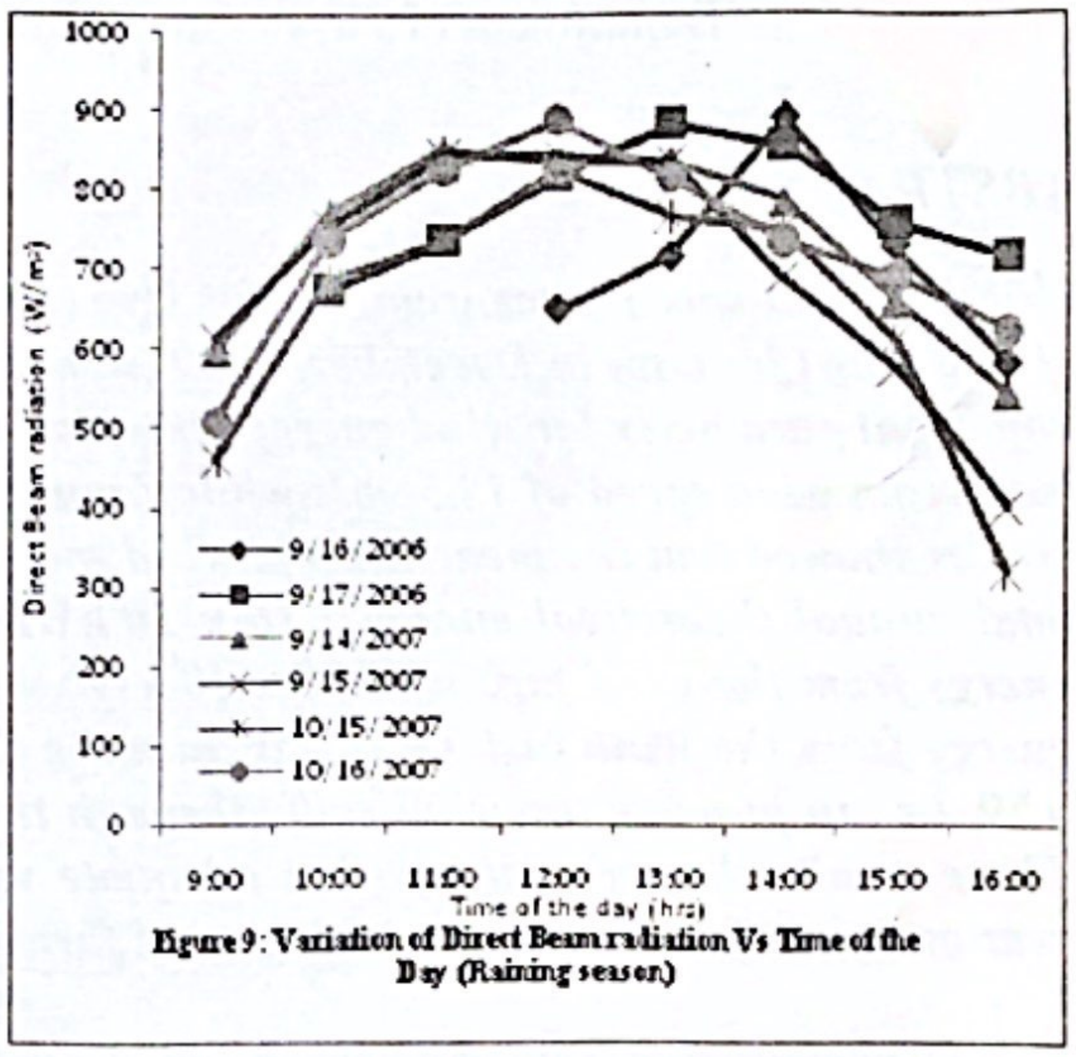


Figure 9: Variation of Direct Beam radiation Vs Time of the Day (Raining season)

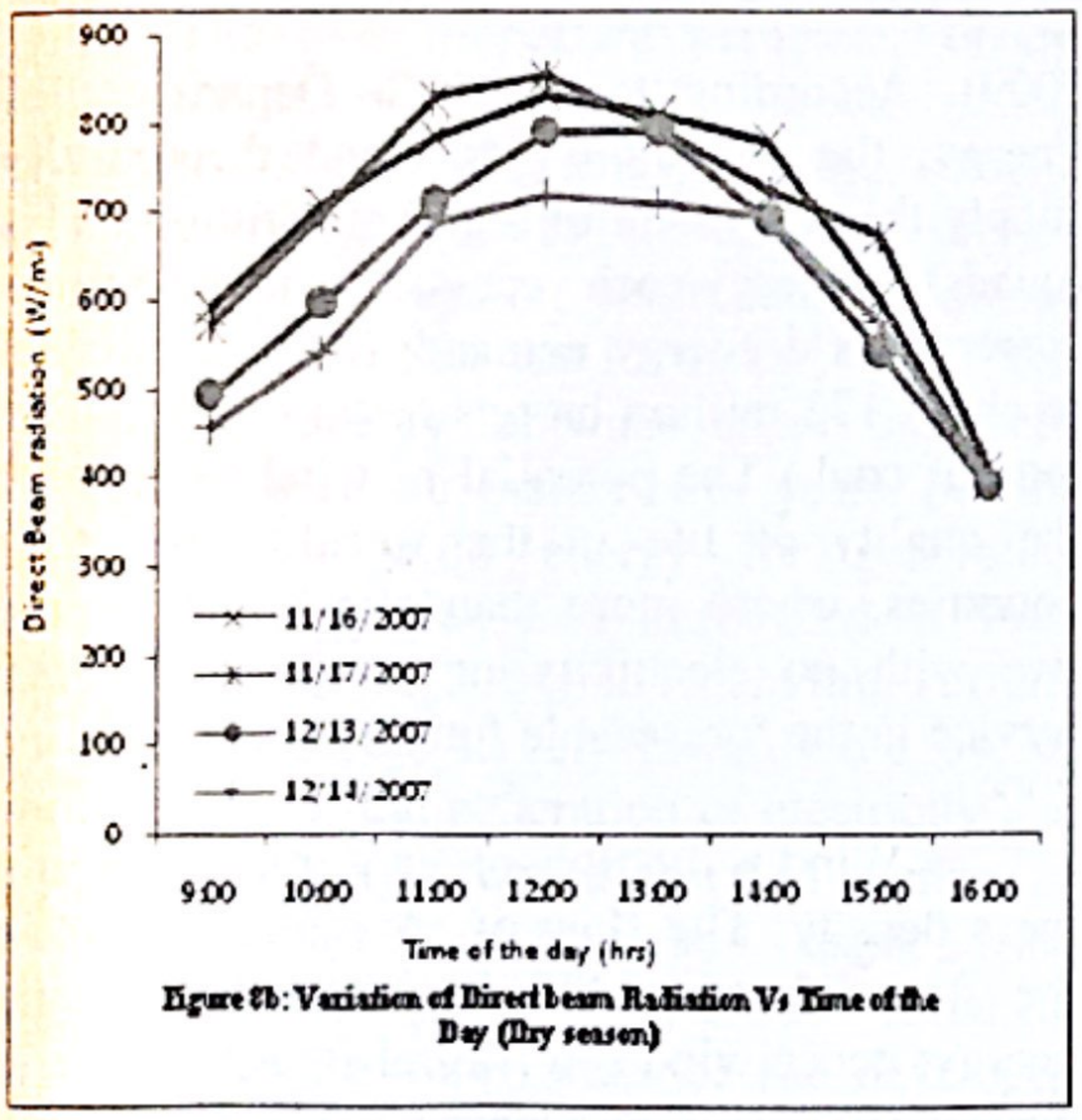


Figure 8b: Variation of Direct beam Radiation Vs Time of the Day (Dry season)