EFFECTS OF MICROCLIMATIC CONDITIONS ON THE EARLY GROWTH OF JATROPHA (*Jatropha curcas (Linn)*) SEEDLINGS IN KANO, NIGERIA

BY

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DECLARATION

I declare that the work in this Dissertation entitled "Effects of Microclimatic Conditions on The Early Growth of Jatropha (*Jatropha curcas (Linn*)) Seedlings in Kano, Nigeria" is a record of my own research work under the supervision of Dr. B.A. Sawa and Dr. I.A. Abdulhamed. The information derived from literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other Institution.

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Name of Student Signature Date

CERTIFICATION

This Dissertation entitled "EFFECTS OF MICROCLIMATIC CONDITIONS ON THE EARLY GROWTH OF JATROPHA (*Jatropha curcas (Linn*)) SEEDLINGS IN KANO, NIGERIA" by Isa ADAMU, meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This research work is dedicated to my beloved parents; my late father Alhaji Adamu Muhammad, who died on Tuesday the 23rd day of January, 1990 may his gentle soul rest in perfect peace, Ameen. And my beloved mother Hajiya Fatima Isa, for their unflinching support; financially, morally and otherwise throughout my educational career, may Allah reward them with Al-Jannah Firdausi (Paradise) Ameen. I also dedicate this work to my beloved children; Fatima, Safiyya and Nana Aisha for their prayers, patience and love.

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ABSTRACT

This study examined the effects of microclimatic conditions on the early growth of *Jatropha curcas* seedlings in Kano, Nigeria. The experiment was conducted between 20 April, 2014 and 14 July, 2014. Microclimatic condition values were recorded using two Lascar EL- USB Data Loggers, one at each of the two treatments (shade and sun). Early growth characteristics of *Jatropha curcas* seedlings at both shade and sun treatments were recorded at 2, 4, 6, 8, 10 and 12 weeks after sowing (WAS). Line and bar graphs were used to describe the microclimatic conditions and the early growth characteristics of *Jatropha curcas* at both shade and sun treatments. Pearson's product moment correlation was used to test whether there is significant relationship between the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings at the two treatments. Paired student t-test was used to determine if there is a significant difference in microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings between the two treatments. All tests were carried out at 0.05 significant levels. The findings of the study revealed that the seedlings in the sun treatment grow faster and gave better results than their shade counter parts. This confirms the effects of sun light on plants and the vital role it plays especially during photosynthesis. The correlation results showed that there is a significant relationship between the micro climatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the sun treatment and also between

dew and seedlings emergence in both shade and sun treatments however; it showed that there is no significant relationship between the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the shade treatment. The student t-test results showed that there is a significant difference in temperature, plant height, stem diameter, leaf count and crop growth rate between the shade and sun treatments. However, it showed that there is no significant difference in relative humidity, dew, seedlings emergence, leaf area, fresh weight and dry weight between the two treatments. Finally, it is recommended that Farmers or Entrepreneurs in the study area should raised *Jatropha curcas* seedlings in an open space to avoid shading effect as this will allow the seedlings to absorb more sunlight for photosynthesis and other growth processes.

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LIST OF ACRONYMS

CGR	Crop Growth Rate
Cm	Centimetre
cm^2	Centimetre Square
cm^3	Centimetre Cube
CRD	Completely Randomized Design
DW	Dry Weight
EFN	Eco Friendly Nets
EL-USB	Lascar Electronic Universal Serial Bus
FAO	Food and Agricultural Organization
FRC	Floating Row Covers
FW	Fresh Weight
G	gram
g/plant	gram per plant
g/wk	gram per week
HT	Height
ITD	Inter-tropical Discontinuity
LA	Leaf Area
LAI	Leaf Area Index
LC	Leaf Count
Nd	No date
RPM	Revolutions Per Minute
SD	Stem Diameter

SPSS	Statistical Package for Social Science
SVF	Sky View Factor
T	Temperature
TA	Titratable Acidity
TSS	Total Soluble Solid
VPD	Vapour Pressure Deficit
WAS	Weeks After Sowing
^{o}c	Degree Celsius
%	Percentage
% rh	Percentage Relative Humidity

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

Climate is typically considered to be a regional phenomenon, describing the long term weather patterns of a large area. Yet even within a small locality, there are variations in temperature, humidity, wind speed and precipitation that can have impact on the organisms that live there (Colliver & Mc Rae, 2011).

Microclimates are small-scale climates which develop both upwards and downwards from the ground surface where radiant energy and precipitation are received and dissipated. They are regions of great variability in both time and space as a result of variation in weather conditions, terrain, vegetation cover, and soil properties (Caborn, 1973).

Microclimate plays an important role in the successful establishment of seedlings. Light, temperature, and moisture influence many of the important physical and physiological processes that affect seedling survival and growth. Low light levels significantly reduce net photosynthesis, as do air temperatures below 5^{o}C and above 30°C (Spittlehouse & Stathers, 1990). If root zone soil dries appreciably, net photosynthesis also declines as the seedling experiences increasing levels of water stress. Extremes of light, temperature, and moisture can physically damage and sometimes kill seedlings (Spittlehouse & Stathers, 1990). Usually the adverse effects of climate are only noticed when lethal damage occurs. However, sublethal effects are also important because they can reduce the growth potential of the seedling, increase its vulnerability to additional environmental stresses, and increase its susceptibility to disease and insect infestation. For reforestation to be successful, it is important that the forester match the silvical requirements of the species to be regenerated to the site environment. Failure to consider the seedling environment can lead to either a complete plantation failure or the creation of an off-site plantation that might grow slowly or be repeatedly damaged by adverse weather (Spittlehouse & Stathers, 1990).

Air temperature and relative humidity, which are the focus of this study, are two key meteorological parameters influencing plant growth. Temperature is directly linked to metabolic rates. Relative humidity influences a plant's loss of water due to transpiration to fix a certain amount of carbon dioxide (CO_2). The water vapour content of the air (the vapour pressure or vapour density) directly affects the atmospheric evaporative demand on seedlings and, therefore, the seedling transpiration rate. Prolonged high evaporative demand for moisture can cause seedling water stress and a subsequent reduction of growth (Von Arx, Dobbertin & Rebetez, 2012).

Seedling transpiration rates are influenced by the vapour pressure deficit which is the difference between the vapour pressure in the leaf (which depends on needle temperature) and the vapour pressure of the air adjacent to the leaf. Vapour pressure deficits usually reach a maximum in the mid-afternoon when air and needle temperatures are highest. The relative

humidity of the air is the ratio of the actual vapour pressure to the saturation vapour pressure. Increasing the vapour pressure deficit (decreasing the relative humidity) of the air increases the evaporative demand, and increases the potential for plant water stress. Winter desiccation often occurs when needles are exposed to air with a low relative humidity (Spittlehouse & Stathers, 1990).

Air temperature has a considerable influence on seedling growth and survival. Physiological processes such as photosynthesis and respiration involve biochemical reactions that are temperature-dependent. Physical processes such as transpiration are also temperature dependent. Growth rates are usually suboptimal when temperatures are below 15°C, optimal in the 15 to 25°C range, and increasingly suboptimal as temperatures rise above 30°C. Physical tissue damage and mortality can occur if temperatures exceed about 50°C. The degree and extent of damage, however, depends on the duration and intensity of high temperatures as well as on the type of tissue that is affected (Spittlehouse & Stathers, 1990). For survival and growth of young tree seedlings for instance, favourable temperature, air humidity and soil moisture are crucial determinants, especially when the root system is sufficiently developed and other factors such as light conditions and nutrient availability become limiting (Wicklein, Christopher, Carter & Smith, 2012). Temperature affects rates of metabolism and growth and influences plant water demand. Similarly, soil temperature has been shown to influence root water uptake and thus transpiration rates (Mellander, Bishop & Lundmark, 2004).

Canopy and tree stems partly shield near ground areas from solar radiation and reduce mixing of air. As a consequence, below-canopy microclimate may substantially differ from comparable open areas (Geiger, 1927; Geiger, Aron & Todhunter, 2009). While shading by the canopy affects soil and air temperature, the direct effect on air temperature is assumed to be smaller, mainly because air is mobile, as well as partly mixed and exchanged with the open area (Von Arx, Pannatier, Thimonier & Rebetez, 2013).

Jatropha Curcas is a small tree or shrubs with smooth gray bark which extrudes whitish coloured watery latex when cut. It is commonly refered to as physic nut or American purging nut. In Nigeria, it is called *Bini da Zugu* in Hausa," *odo- ala*" in Igbo, " *Lapalapa or Botuje*" in Yoruba and "*Ujara*" in Edo (Adeoye, *et al.*, 2011). It belongs to the family of Euphorbiaceae which normally grows in the tropics. It can grow almost anywhere and it is a drought resistant and perennial crop. It is easy to establish, grows relatively quickly and lives for 40-50years. Its productive life is from 30- 40 years. The hardy *Jatropha curcas* is resistant to drought and produce seeds containing 32-40 % oil. When the seeds are crushed and processed, the resulting oil can be refined to diesel engine, while the residue can also be processed into biomass to power electricity plants and organic fertilizer and it is one of the best plants for future bio-diesel production (FACT Foundation, 2010).

Jatropha curcas grows almost anywhere even on gravel, sandy and saline soils. The best soils for Jatropha are aerated sands and loams of at least 45 cm depth (Gour, 2006). Heavy clay soils are less suitable and should be avoided, particularly where drainage is impaired, as Jatropha

is intolerant of waterlogged conditions. Ability to grow in alkaline soils has been widely reported, but the soil pH should be within 6.0 to 8.0/8.5 (FACT Foundation, 2007). Although a native of tropical America, it now thrives throughout Africa and Asia. It can thrive on the poorest stony soil, and can grow even in the crevices of rocks. However, survival ability does not mean that high productivity can be obtained from Jatropha under marginal agricultural environments. It grows in a number of climate zones in tropical and sub tropical regions of the world and can be grown in areas with high and low rainfall conditions. It grows well in areas with rainfall of 500-750mm and can tolerate high rainfall up to 1200mm. It can withstand long period of drought by shedding most of its leaves to reduce transpiration loss (Gour, 2007). There is evidence from northwest India that Jatropha is tolerant of saline irrigation water, although yield under these conditions is not documented (Dagar *et al*., 2006).

1.2 Statement of the Research Problem

Despite the large interest *Jatropha curcas* plant has attracted recently in the World, there is still need for more research on its agronomic characteristics and nursery practices in Nigeria. Information is still required to examine the effects of microclimatic conditions on the early growth of *Jatropha curcas* seedlings.

Nursery grown *Jatropha curcas* seedlings have a higher chances of survival than the direct seeded in the field and they produce seeds earlier (Da schio, 2010). Also Kaushik (2007) recommended the use of seedlings raised by seed for dry areas because they produce deep and straight tap roots. Therefore, the study of raising seedlings in the nursery becomes of paramount importance especially that of effects of microclimatic conditions on the early growth of *Jatropha curcas* seedlings in Kano, Nigeria where little or no research have been carried out by researchers on that aspect.

Cavieres, Badano, Sierra-Almeida and Molina- Montenegro (2005) evaluated the modifications on soil temperature and moisture over an entire growing season by two cushion species (*Laretia acaulis* and *Azorella monantha*) in alphine communities located at two different elevations in the central Chilean Andes. Additionally, the study performed seedling survival experiments with two native herbaceous species (*Hordeum comosum* and *Erigeron andicola*) and the non native forb (*Cerastium arvense*) to assess if seedling survival is higher within cushions than outside them. Their result indicated that cushions ameliorated extreme low and high substrate temperatures, improved soil moisture, and enhanced seedling survival of the three herbaceous plant species they evaluated. Their result suggests that microclimatic modifications associated with cushion plants could be important for the establishment and survival of other plant species, both native and non native, in the high alpine communities of central Chile.

Even though Cavieres *et al*. (2005) studied microclimatic conditions, their work did not investigate the early growth characteristics of *Jatropha curcas* plant and they did not investigate dew. Their main concern was to evaluate modifications on soil temperature and moisture and also assess seedlings survival. The study was also conducted in temperate region of the world. This study is designed to fill this knowledge gap.

Oliet and Jacobs (2007) examined microclimatic conditions under a controlled environment using mesic and xeric watering regimes within light and dark tree shelters relative to non-sheltered conditions and corresponding influences on morpho-physiological development of holm oak (*Quercus ilex L*.) seedlings during initial establishment. The study concluded that microclimatic conditions within tree shelters and corresponding influences on plant morpho-physiological development are interrelated through complex phenomena dependent upon environmental conditions and phenotypic characteristics of a given plant species. In addition the study concluded that shelter configurations must be adapted to match climatic conditions of the out planting site with species plasticity, and recommended light shelters with high light transmittance for planting holm oak in Mediterranean areas.

Oliet and Jacobs (2007) did not address the issue of nurturing seedlings in the sun (open space); the study was conducted in a green house in United States of America. The work was not on *Jatropha curcas* plant. The study did not investigate the early growth characteristic of the plant species studied and dew was also not investigated in the micro climatic elements. Therefore there is need to fill this gap in knowledge.

In Senegal, Ndiaye *et al.* (2008) conducted a study on seed germination, growth rate, propagation by seeds and cuttings and micro propagation of *Jatropha curcas* in green house conditions and in the fields. The study found out that percentage germination under green house conditions was 86% and the in vitro germination was difficult to achieve due to seed infections while coatless seeds allowed only 20% germination. The three month old seedlings reached a mean height growth of 24.3cm. The overall survival of seedlings in Ndiol station was 99.4% for planted seedlings and 60% for cuttings four weeks after planting.

Even though, Ndiaye *et al.* (2008) conducted a study on *Jatropha curcas* plant, they only investigate its height as an early growth parameter. The work did not investigate microclimatic elements such as air temperature, relative humidity and dew. The main aim of the study was to investigate seed germination, growth rate, propagation by seeds and cuttings and micro propagation of *Jatropha curcas* in green house conditions and in the fields in Senegal. Therefore it is pertinent to examine the effects of microclimatic conditions on the early growth of *Jatropha curcas* seedlings in Kano, Nigeria.

In Nigeria, Adeoye, *et al.* (2011) studied the effect of tree canopy on the early growth of *Jatropha curcas* seedlings. The study consist of three treatments in which 15 seedlings were placed under *Gmelina* (T1), 15 seedlings were placed under *Bambussa vulgaris* stand (T2) and 15 seedlings were placed in an open space (T3) making a total of 45 seedlings all together.

Adeoye, *et al*. (2011) observed the growth parameters of *Jatropha curcas* seedlings such as the stem height, stem diameter and leaf count. The experiment covers twelve weeks with 8 weeks of thorough observation, measurement and recording of data. They found out that seedlings placed under *Bambussa vulgaris* canopy gave the best performance in terms of leaf count and stem diameter while seedlings placed in the open space gave the best performance in terms of stem height. Finally, they recommend that for proper growing of *Jatropha curcas* seedlings, seedlings should be raised under *Bambussa vulgaris* canopy as this will provide a

modulating effect on the microclimatic condition under which the growth condition of *Jatropha curcas* seedlings can be modified and improved naturally.

The study of Adeoye, *et al.* (2011) did not address the issue of microclimatic elements such as air temperature, relative humidity and dew effects on the early growth of the *Jatropha curcas* plant, and the study was conducted in Ibadan, Oyo State, south western part of Nigeria which is a tropical rain forest environment. Their primary concern was to study the effect of tree canopy on the early growth of *Jatropha curcas* seedlings. It is however, important to find out the effects of microclimatic elements (air temperature, relative humidity and dew) on the early growth of *Jatropha curcas* seedlings in Kano, Nigeria. Therefore, this study is design to answer the following questions.

i. What are the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the shade and sun treatments?

ii. What is the relationship between the microclimatic conditions and the early growth characteristics of the *Jatropha curcas* seedlings in the shade and sun treatments?

iii. What is the difference in the microclimatic conditions and the early growth characteristics of the *Jatropha curcas* seedlings between the shade and sun treatments?

1.3 Research Aim and Objectives

The aim of this study is to examine the effects of microclimatic conditions on the early growth of *Jatropha curcas* seedlings in Kano, Nigeria. The specific objectives are to:

i. investigate the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the shade and sun treatments.

ii. examine the relationship between the microclimatic conditions and the early growth characteristics of the *Jatropha curcas* seedlings in the shade and sun treatments.

iii. determine the difference in the microclimatic conditions and the early growth characteristics of the *Jatropha curcas* seedlings between the shade and sun treatments.

1.4 Hypotheses

The null hypotheses are stated thus:

i. There is no significant relationship between the micro climatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in both shade and sun treatments.

ii. There is no significant difference in the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings between the shade and sun treatments.

1.5 Scope of the Study

This study focuses on the early growth of *Jatropha curcas* seedlings at Forestry Research Institute of Nigeria, Shelterbelt Research Station Nursery, Kano. It is an experimental study aimed at examining the effect of microclimatic conditions on the early growth of *Jatropha curcas* seedlings. The study covered a period of twelve (12) weeks (3 months) that is from 20 April, 2014 to 14 July, 2014 and only data on the number of days to seedlings' emergence, plant height, stem diameter, leaf area, number of leaves per plant, fresh weight of whole plant per plant, dry weight of whole plant per plant and crop growth rate (CGR) per plant of the *Jatropha curcas* seedlings were measured. However, emphasis was also given to the microclimatic conditions of the nursery and data on only the air temperature, relative humidity and dew was measured.

1.6 Justification of the Study

Tree shelters are used commonly under a wide range of agriculture and forestry applications, and the presence of the shelter is known to influence plant development through shelter–plant interactions that affect microclimatic conditions (Oliet & Jacobs, 2007). However, effects of tree shelter microclimates on the early growth of *Jatropha curcas* seedlings in Kano, Nigeria have yet to be examined.

Jatropha is a genus of approximately 175 succulent plants, shrubs and trees (some are deciduous, like *Jatropha curcas* L.*)*, from the family Euphorbiaceae. *Jatropha curcas* L. is a drought resistant perennial, growing well in marginal/poor soil. It is easy to establish, grows relatively quickly and lives, producing seeds for 50 years. *Jatropha* the wonder plant produces seeds with an oil content of 37%. The oil can be combusted as fuel without being refined. It burns with clear smoke-free flame, tested successfully as fuel for simple diesel engine (Azza, Mazhar, Abd El Aziz & El. Habba, 2010).

Economically, *Jatropha curcas* has gained considerable recognition in the mid '90's as an alternative source of fuel or lighting in low Revolutions Per Minute (RPM) diesel combustion engines and a potential source of bio-diesel for trucks and cars. Besides, about one third of the

energy in the fruit of *Jatropha* can be extracted as oil. It has a similar energy value to diesel fuel and can meet the cooking and lighting needs of the rural population and boiler fuel for industrial purposes. *Jatropha* oil can be produced from locally grown *Jatropha* plants and it can be used directly in diesel engines (Food and Agriculture Organization of the United Nations, 2010). Being drought tolerant, it can be used to reclaim eroded areas and it has the ability to grow on marginal land. It is used for desertification and erosion control and for preventing shifting of sand dunes (Sand dunes fixation). However, the cost of producing *Jatropha* oil as a diesel substitute is currently higher than the cost of petrol diesel itself that is either subsidize or not priced at "full cost" because of misgoverned and distorted national energy policies Adeoye, *et al*. (2011). Nevertheless, the environmental benefit of substituting petrol with plant oil makes the option highly desirable.

Jatropha oil has a very high saponification value and is being extensively used for making soap in some countries. Also, the oil is used as an illuminant as it burns without emitting smoke. The latex of *Jatropha curcas* contains an alkaloid known as Jatrophine which is believed to have anti-cancerous properties. It is also used as an external application for skin disease and rheumatism and for sores on domestic livestock. In addition, the tender twig of the plant is used for cleaning teeth while the juice of the leaf is used as an external application for piles. The root is also reported to be used as an antidote for snake bites. The bark of *Jatropha curcas* yields a dark blue dye which is used for colouring cloth and fishing poison (FAO, 2010). Its leaves are used as food for the silkworm. In Brazil, the leaves are used for fumigating houses against bed bugs. It has been so successful that consideration is now been given to building a factory to produce insecticide on commercial scale. Its oil cake is rich in Nitrogen, phosphorus and potassium and can be used as Organic manure (Adeoye, *et al*., 2011).

Jatropha curcas has been recognized worldwide as suitable specie for biodiesel production and sand dune fixation in arid zones. It is a common growing plant in Nigeria where it is widely used as a live fence. With the global recognition of its attributes for biodiesel production and desertification control, there is need to determine the best microclimatic condition suitable for large scale seedlings production of the specie which might be adopted by a farmer or entrepreneur.

Information obtained from this study will direct research efforts towards developing a microclimatic condition that will be suitable for large scale production of the specie seedlings and maximizing its potentials for various uses.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter reviews related literature on the effects of microclimatic conditions on the early growth of *Jatropha curcas* seedlings. The chapter is divided into five sections. The first section discusses microclimates, the second microclimates and plants growth, the third reviews the effects of microclimatic conditions on seedlings growth, the fourth on *Jatropha curcas*- its origin, biology and uses while the last reviews the effects of microclimatic conditions on *Jatropha curcas* Seedlings.

2.2 Microclimates

Microclimate is a sort of climatic condition measured in localized areas near the earth's surface (Geiger1965, cited Chen *et al*, 1999). These environmental variables, which include temperature, light, wind speed, and moisture, have been critical throughout human history, providing meaningful indicators for habitat selection and other activities. For example, for 2600 years the Chinese have used localized seasonal changes in temperature and precipitation to schedule their agricultural activities (Geiger1965, cited Chen *et al*, 1999). In seminal studies, Shirley (1929), (1945), cited in Chen *et al*, 1999, emphasized microclimate as a determinant of ecological patterns in both plant and animal communities and a driver of such processes as the growth and mortality of organisms. The importance of microclimate in influencing ecological processes such as plant regeneration and growth, soil respiration, nutrient cycling, and wildlife habitat selection has became an essential component of current ecological research (Perry 1994, cited Chen *et al*, 1999).

Microclimate has been defined by Croker (1956) as the climatic environment of a very local area, such as the north- or the south-facing slope of a hill, or an even smaller area. It refers strictly to local combinations of atmospheric factors, which differ from the macroclimate because of uneven topography or differences in plant cover. Within the area of one macroclimate there may exist a whole series of microclimates some of which may differ sufficiently to be of ecological importance (Croker, 1956).

Cramer (2001) also defined microclimate as the climate of a small area that is different from the area around it. It may be warmer or colder, wetter or drier, or more or less prone to frosts. Microclimates may be quite small - aprotected courtyard next to a building, for example, that is warmer than an exposed field nearby. Or a microclimate may be extensive - a band extending several miles inland from a large body of water that moderates temperatures (Cramer, 2001).

Again, the National Meteorological Library and Archive (2011) defined microclimate as the distinctive climate of a small-scale area, such as a garden, park, valley or part of a city. The weather variables in a microclimate, such as temperature, rainfall, wind or humidity, may be subtly different to the conditions prevailing over the area as a whole and from those that might

be reasonably expected under certain types of pressure or cloud cover. Indeed, it is the mixture of many, slightly different microclimates that actually makes up the climate for a town, city or wood (NMLA, 2011).

The existence of microclimates has long been recognized in its practical application in the importance of aspect and contour in determining the climate of local areas. It has been recognized in the difference between sunny and shady slopes in hill country; in the occurrence of cold air drainage and frost in the siting of crops and orchards; in the tolerance of forest trees to shading and its relation to natural regeneration; and even in the choice of position for the different plants in the home garden (Croker, 1956).

Apart from the practical applications in forestry and agriculture, research on microclimate has been confined to the habitats of a few plants and animals. The main source of inspiration for studies of microclimate has been the work of the meteorologist R. Geiger (1927, 1942 cited in Croker, 1956) who showed that the climate near the ground differed from the macroclimate because of the effect of the ground and the presence of a plant cover. Microclimate differs from micro meteorology since it is concerned with the local atmospheric conditions as they affect the living conditions of plants and animals, and not with the mechanics of the weather itself. The factors measured are the same as in ordinary meteorological studies, but the type of ground, the presence of vegetation and the type of plant are important in determining the microclimate.

Geiger was the first to demonstrate the steep temperature gradients which exist above the ground or vegetation surfaces, often amounting to 15°C in 45.72cm. The greatest extremes of temperature (that is the highest day-time and the lowest night-time temperature) occur at what is known as the outer active surface. This is the surface at which the sun's energy is absorbed and from which it is radiated and is either the surface of the ground or the region of maximum leaf development of the plant cover; here the temperature fluctuates more widely in 24 hours than does the air temperature.

Where there is free air movement there is no difference in air temperatures in the sun and the shade, but in the absence of wind the hot air formed over bare areas rises vertically during the day and has little influence on the air temperature under the adjacent shade, but during the night cold air formed over the open ground spreads out under the adjacent cover (Croker, 1956).

Even a thin cover of vegetation reduces the heating of the soil by the sun, and in the shade the soil surface temperatures remain less than the air temperatures, even in the hottest part of the day. At night the rate of loss of heat is retarded by a plant cover and the temperature of the soil does not drop as low as on adjacent open areas. Thus because of the opposite effects of vegetation during the day and during the night there is less fluctuation in temperature under a plant cover (Croker, 1956).

Daily maximum temperatures may be higher above a plant cover than at an equal distance above bare ground if the plants are too widely spaced to shade the ground but are effective in preventing wind from blowing away the heated air. Similarly night minimum

temperatures may be lower if the wind moves the air over bare areas but does not move the cold air which settles among the plants (Croker, 1956).

The presence of plants reduces the steepness of the temperature gradients above bare earth and the type of plant changes the height at which the outer active surface occurs. Geiger measured the temperature gradients in different types of vegetation and found that in a bed of Antirrhinums the daily maxima occurred at the upper leaf surface but in rye was distributed down the stems; at night temperature inversion occurred in the Antirrhinums but not in the rye because the close stems impeded air movements. The latent heat of evaporation of the water produced by transpiration from the plants has a damping effect, similar to the formation of dew, which results in a considerable reduction in the amount of cooling which occurs at the soil surface (Croker, 1956).

In valleys where temperature inversion on a large scale occurs at night, a layer of warm air is formed between two cold layers. Where this belt of warm air meets the valley sides the 'thermal belt' is formed. This is a well-known phenomenon in mountainous areas, especially in Europe where orchards and vineyards are located in the thermal belt to escape the late spring and early autumn frosts which occur on the valley floor below.

The nature of the soil surface has a great influence on the amount of temperature change, a sandy soil being warmer and undergoing a greater range of temperature fluctuation than a forest or bog soil. The wetter the soil the slower the temperature change, so patches of impeded drainage in an otherwise well-drained soil will be much colder (Croker, 1956).

2.3 Microclimates and Plants Growth

Several studies were conducted on the effects of microclimates on plants growth. For example Ganesan (1999) study the effect of Poly-Greenhouse on Plant Micro Climate and Fruit yield of Tomato in India. In his study, Ganesan found out that the light intensity inside the greenhouse was lower than in the open and height of the plant, number of nodes, inter nodal length total dry matter production and average fruit weight increased under greenhouse conditions as compared to open field condition. The yield performance inside the greenhouse was higher (2145 g/plant and 2156 g/plant in the first and second season, respectively) than the open field crop. The fruit yield inside the greenhouse was nearly two times more than in the open field condition.

Monteiro, Sentelhas and Chiavegato (2006) studied microclimate and ramulosis occurrence in a cotton crop under three plant population densities in Southern Brazil. They found out that plant density had low effect on air temperature, but differences were found on relative humidity and leaf wetness duration. These differences were observed until the canopy became a continuous surface. The microclimate promoted by plant densities showed to have little influence

on disease progress, since macroclimate during the experiment was favorable to disease development. Genotype IAC 23 was more resistant to ramulosis than Coodetec 401.

Saidi, Gogo, Itulya, Martin, and Ngouajio (2013) conducted an experiment on microclimate modification using eco-friendly nets and floating row covers improves tomato (*Lycopersicon esculentum*) yield and quality for small holder farmers in Kenya, East Africa. They found out that the use of eco-friendly nets (EFN) or floating row covers (FRC) modified the micro- climate with higher temperatures, lower diurnal temperature ranges, and higher volumetric water content recorded compared with the controls. Also, light quantity and photo-synthetic active radiation were reduced by the use of EFN and FRC compared with the controls. Their result revealed that use of FRC and EFN yielded in more fruit and higher percentage in marketable yield compared with open field production. Fruit quality at harvest was also significantly improved by the use of EFN and FRC. Fruits with higher total soluble solids (TSS), lower titratable acidity (TA), and higher sugar acid ratio were obtained in EFN and FRC treatments compared with the controls. Fruits harvested from EFN and FRC were also firmer compared with control fruits. Their findings demonstrated the potential of EFN and FRC in modifying microclimate conditions and improving yields and quality of tomato under tropical field conditions.

2.4 The Effects of Microclimatic Conditions on Seedlings Growth

Cavieres *et. al.,* (2005) conducted an experiment on microclimatic modifications of cushion plants and their consequences for seedling survival of native and non-native herbaceous species in the high Andes of Central Chile. Their result indicated that cushions ameliorated extreme low and high substrate temperatures, improved soil moisture, and enhanced seedling survival of plants. They suggested that microclimatic modifications associated with cushion plants could be important for the establishment and survival of other plant species, both native and non native, in the high alpine communities of Central Chile.

Oliet and Jacobs (2007) examined microclimatic conditions under a controlled environment using mesic and xeric watering regimes within light and dark tree shelters relative to non-sheltered conditions and corresponding influences on morpho-physiological development of holm oak (*Quercus ilex L.*) seedlings during initial establishment in United States of America (USA). They found out that microclimatic conditions within tree shelters and corresponding influences on plant morpho-physiological development are interrelated through complex phenomena dependent upon environmental conditions and phenotypic characteristics of a given plant species. They also report that shelter configurations must be adapted to match climatic conditions of the out planting site with species plasticity; and finally, they recommend light shelters with high light transmittance for planting holm oak in Mediterranean areas.

Devine and Harrington (2008) evaluated four types of tree shelters effects on seedling microenvironment and performance of two tree species in southwestern Washington. They found

out that after planting, in the first year, height and diameter growth of western redcedar (*Thuja plicata* Donn ex D. Don) were significantly increased by all the four shelter types, with blue solid-walled shelters resulting in the greatest height growth. However, in blue solid-walled shelters, photosynthesis and stem diameter growth of Oregon white oak (*Quercus garryana* Dougl. ex Hook.) seedlings were significantly less than for unsheltered seedlings.

Von Arx *et al*., (2012) conducted a long-term experiment of spatio-temporal effects of forest canopy on understory microclimate in Switzerland. Their results confirmed a general moderating effect of canopy on below-canopy microclimate with a decrease of daily maximum air temperature of up to 5.1 ^{o}C (overall average: 1.8 ^{o}C) and an increase of daily minimum relative humidity of up to 12.4% (overall average: 5.1%) in the long-term average, respectively. Broadleaved and non-pine conifer forests moderated daytime microclimate about twice as much as pine forests, while at nighttime considerably less cooling down and even negative effects on levels of relative humidity compared to the open area were recorded at the pine forest sites. Moderating capacity was stronger at low altitude than at high altitude. It was strongest during the growing season, particularly in summer, and depended in a complex way on the general weather situation. Deviations from the general seasonal and weather condition patterns most likely occurred when soil moisture pools were depleted. Despite the moderating capacity, below-canopy microclimate did not lag behind open area microclimate. They finally, conclude based on their results that natural recruitment in pine forests and high-altitude forests may respond most sensitively to climate change.

Another study was conducted in Switzerland by Von Arx *et. al*. (2013) on Microclimate in forests with varying leaf area index and soil moisture: potential implications for seedling establishment in a changing climate. They investigated how temporal patterns of microclimate below sparse and dense forest canopy related to those of nearby open areas and how this relationship was influenced by soil moisture and seasonality in a long-term (1998–2011) trial. Air temperature (T), vapour pressure deficit (VPD), soil matrix potential and leaf area index (LAI) were measured in a unique set-up of below-canopy and open-area meteorological stations at eleven distinct forest ecosystems, characteristic of subalpine and temperate climate zones. They analysed data from the plots for the moderating capacity of the canopy, that is, the differences between below-canopy and open-area microclimate, with respect to long-term means, dynamics within homogeneous moist- vs. dry-soil periods and diurnal patterns. They found out that the long-term mean moderating capacity of the canopy was up to 3.3 °C for daily Tmax and 0.52 kPa for daily VPDmax, of which soil moisture status alone accounted for up to 1.2 °C (Tmax) and 0.21 kPa (VPDmax). Below dense canopy (LAI > 4), the moderating capacity was generally higher when soils were dry and increased during dry-soil periods, particularly in spring and somewhat less in summer. They found out that the opposite pattern was below sparse canopy (LAI < 4). At the diurnal level, moderating capacity below dense canopy was found out to be the strongest in mid-afternoon and during dry-soil conditions, where as peak moderation below sparse canopy occurred in mid-morning and during moist-soil conditions. Their results suggest a threshold canopy density, which is probably linked to site specific Water availability, below

which the moderating capacity of forest ecosystems switches from supportive to unsupportive for seedling establishment. Under supportive moderating capacity, they understand a stronger mitigation during physiologically most demanding conditions for plant growth. Such a threshold canopy density sheds new light on forest resilience to climate change. Climate change may alter forest canopy density in a way that precludes successful establishment of tree species and ultimately changes forest ecosystem structure and functioning.

2.5 Jatropha curcas Plant

Jatropha curcas L., also known as physic nut, purge nut, pig nut or Babados nut is a small tree or shrub belonging to the plant family Euphorbiaceae. In Nigeria it is called *Bini da zugu* or *Cini da zugu* (Hausa), *Kwalkwalaji* (Fulfulde), *Kasha* (Nupe), *odo-ala* (Igbo) and *Lapalapa* (Yoruba).

2.5.1 Origin and Spread of Jatropha

Jatropha is believed to have been spread by Portuguese seafarers from its centre of origin in Central America and Mexico via Cape Verde and Guinea Bissau to other countries in Africa and Asia (FAO, 2010). It is now widespread throughout the tropics and sub-tropics. Until recently, Jatropha had economic importance in Cape Verde. Since the first half of the nineteenth century, with its ability to grow on poor soils with low rainfall, it could be exploited for oilseed production. Cape Verde exported about 35,000 tonnes of Jatropha seeds per year to Lisbon. Along with Madagascar, Benin and Guinea, it also exported Jatropha seeds to Marseille where oil was extracted for soap production. However, this trade declined in the 1950s with the development of cheaper synthetic detergents and, by the 1970s, the trade in Jatropha oil had disappeared (Wiesenhutter, 2003; Henning, 2004a cited FAO, 2010).

In the past, Jatropha oil was used for lighting lamps. Today, rural communities continue to use it for its medicinal value and for local soap production. India and many countries in Africa use the Jatropha plant as a living hedge to keep out grazing livestock. Jatropha is planted in Madagascar and Uganda to provide physical support for vanilla plants (Gubitz, Mittelbach & Trabi, 1999).

Jatropha's potential as a petroleum fuel substitute has long been recognized. It was used during the Second World War as a diesel substitute in Madagascar, Benin and Cape Verde, while its glycerine by-product was valuable for the manufacture of nitro-glycerine.

2.5.2 Nomenclature and Taxonomy of Jatropha

Jatropha curcas L. was first described by Swedish botanist Carl Linnaeus in 1753. It is one of many species of the genus *Jatropha*, a member of the large and diverse *Euphorbiaceae* family. Many of the *Euphorbias* are known for their production of phytotoxins and milky white sap. The common name "spurge" refers to the purgative properties of many of these *Euphorbias* (FAO, 2010). Below is the botanical classification of the Jatropha plant;

Class: Rosidae
Order: Malpighiales
Family: Euphorbiaceae
Sub-Family: Crotonoideae
Tribus: Jatropheae
Genus: Jatropha
Species: Jatropha curcas L

There are some 170 known species of Jatropha, mostly native to the New World, although 66 species have been identified as originating in the Old World (Heller, 1996 cited FAO, 2010). A number of jatropha species are well known and widely cultivated throughout the tropics as ornamental plants. The literature identifies three varieties: Nicaraguan (with larger but fewer fruits), Mexican (distinguished by its less-toxic or non-toxic seed) and Cape Verde. The Cape Verde variety is the one commonly found throughout Africa and Asia. *Jatropha curcas* L. has many vernacular names including: physic nut or purging nut (English), *pinhão manso* or *mundubi-assu* (Brazil), *pourghère* (French), *purgeernoot* (Dutch), *Purgiernuss* (German), *purgeira* (Portuguese), *fagiola d'India* (Italian), *galamaluca* (Mozambique), *habel meluk* (Arab), *safed arand* (Hindi), *sabudam* (Thai), *bagani* (Ivory Coast), *bini da zugu* (Nigeria), *makaen* (Tanzania), *piñoncillo* (Mexico), *tempate* (CostaRica) and *piñon* (Guatemala).

2.5.3 Description of Jatropha

Jatropha, a succulent perennial shrub or small tree, can attain heights of more than 5 metres, depending on the growing conditions with spreading branches and stubby twigs, exuding milky or yellowish latex. Seedlings generally form a central taproot, four lateral roots and many secondary roots. The leaves, arranged alternately on the stem, are shallowly lobed and vary from 6 to 15cm in length and width. The leaf size and shape can differ from one variety to another. As with other members of this family, the vascular tissues of the stems and branches contain white latex. The branches and stems are hollow and the soft wood is of little value (see plate 2.1).

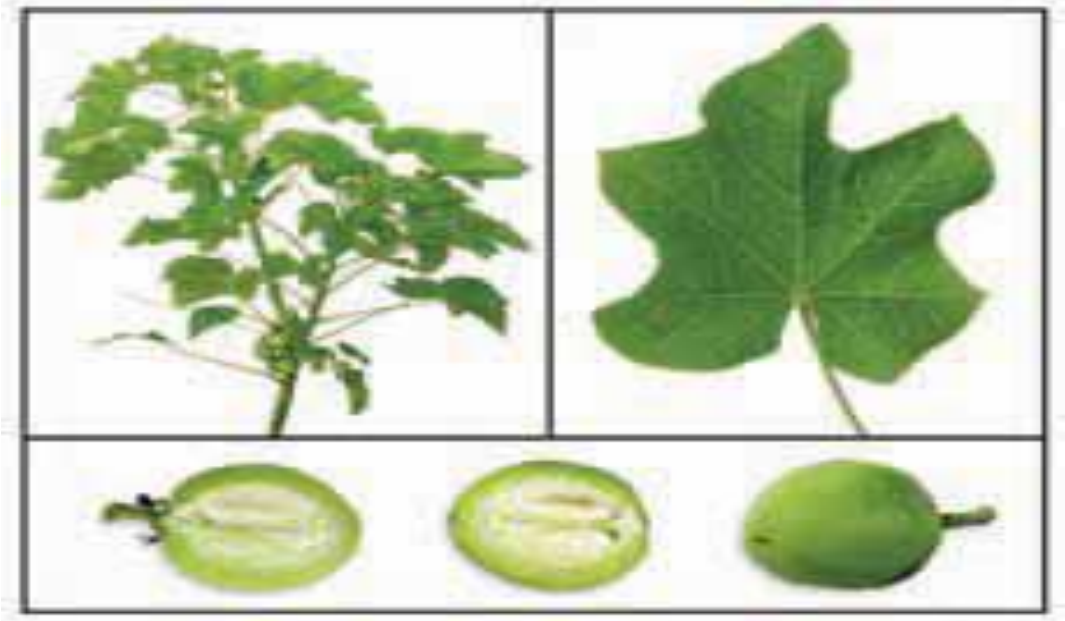


Plate 2.1: A flowering *Jatropha curcas* plant in Shelterbelt Research Station, Kano Orchard

Jatropha is monoecious, meaning it carries separate male and female flowers on the same plant. There are fewer female than male flowers and these are carried on the apex of the inflorescence, with the more numerous males borne lower down. The ratio of male to female flowers averages 29:1 but this is highly variable and may range from 25-93 male flowers to 1-5 female flowers produced on each inflorescence (Raju and Ezradanum, 2002 cited FAO, 2010). It also has been reported that the male-to-female flower ratio declines as the plant ages (Achten *et al.*, 2008), suggesting that fruiting capacity may increase with age.

The unisexual flowers of Jatropha depend on pollination by insects, including bees, flies, ants and thrips. One inflorescence will normally produce 10 or more fruits. Fruit set generally results from cross pollination with other individual plants, because the male flowers shed pollen before the female flowers on the same plant are receptive. In the absence of pollen arriving from other trees, Jatropha has the ability to self pollinate, a mechanism that facilitates colonization of new habitats (Raju and Ezradanum, 2002 cited FAO, 2010).

The fruits are ellipsoidal, green and fleshy, turning yellow and then brown as they age (see plate 2.2). Fruits are mature and ready to harvest around 90 days after flowering. Flowering and, therefore, fruiting are continuous, meaning that mature and immature fruits are borne together. Each fruit contains two or three black seeds, around 2 cm x 1 cm in size. On average, the seeds contain 35 percent of non-edible oil.



Source: Adopted from FAO (2010)

Plate 2.2: Jatropha leaf and fruit

Jatropha grows readily from seed which germinate in around 10 days, or from stem cuttings. Plants from seeds develop a typical tap root and last longer in plantations where as stem cuttings do not develop tap roots (Heller, 1996, cited Abubakar, 2010). Heller, 1996 cited FAO (2010) maintained that the Jatropha growth is rapid, and that the plant may reach one metre and flower within five months under good conditions. The growth is sympodial, with terminal flower inflorescences and lateral branching, eventually reaching a height of 3 to 5 metres under good conditions. It generally takes four to five years to reach maturity (Henning, 2008a cited FAO, 2010). Vegetative growth occurs during the rainy season. During the dry season, there is little growth and the plant will drop its leaves. Flowering is triggered by rainfall and seed will be produced following the end of the rainy season. Seeds are produced in the first or second year of growth. Jatropha trees are believed to have a lifespan of 30 to 50 years or more (FAO, 2010).

2.5.4 Jatropha Climatic Requirement

Jatropha grows in tropical and sub tropical regions, with cultivation limits at 30ºN and 35ºS. It also grows in lower altitudes of 0-500 metres above sea level (see Figure 2.1). Jatropha is not sensitive to day length (flowering is independent of latitude) and may flower at any time of the year (Heller, 1996, cited FAO, 2010).



Figure 2.1: Global Indication of the most Suitable Climate Condition for the Growth of Jatropha (J.Caucas L) (30^0 N, 35^0 S) and Oil Palm (Elaeis guineessis Jacq) (4^0 N, 8^0 S)

Source: Adopted from Reinhard (2009)

It is a succulent shrub that sheds its leaves during the dry season, with deep roots that make it well suited to semi-arid conditions. While Jatropha can survive with as little as 250 to 300 mm of annual rainfall, at least 600 mm are needed to flower and set fruit. The optimum rainfall for seed production is considered between 1,000 and 1,500 mm (FACT, 2007,), which corresponds to subhumid ecologies. While Jatropha has been observed growing with 3,000 mm of rainfall (Foidl, 1996, cited Achten, 2008), higher precipitation is likely to cause fungal attack and restrict root growth in all but the most free-draining soils. *Jatropha curcas* is not found in the more humid parts of its area of origin, Central America and Mexico.

Rainfall induces flowering and, in areas of unimodal rainfall, flowering is continuous throughout most of the year. Optimum temperatures are between 20˚C and 28˚C. Very high temperatures can depress yields (Gour, 2006, cited FAO, 2010). Jatropha has been seen to be intolerant of frost. The plant is well adapted to conditions of high light intensity (Baumgaart, 2007, cited Jongschaap, Corre, Bindraban & Bradenburg, 2007) and is unsuited to growing in shade.

2.5.5 Jatropha Soil Requirement

The best soils for Jatropha are aerated sands and loams of at least 45 cm depth (Gour, 2006). Heavy clay soils are less suitable and should be avoided, particularly where drainage is impaired, as Jatropha is intolerant of waterlogged conditions. Ability to grow in alkaline soils has been widely reported, but the soil pH should be within 6.0 to 8.0/8.5 (FACT, 2007). There is evidence from northwest India that Jatropha is tolerant of saline irrigation water, although yield under these conditions is not documented (Dagar *et al*., 2006).

Jatropha is known for its ability to survive in very poor dry soils in conditions considered marginal for agriculture, and can even root into rock crevices. However, survival ability does not

mean that high productivity can be obtained from Jatropha under marginal agricultural environments.

Being a perennial plant in seasonally dry climates, soil health management under Jatropha production would benefit from conservation agriculture practices. This would result in minimum soil disturbance, an organic mulch cover on the soil surface and legume cover crops as intercrops.

Azza, *et. al* (2010) studied the Impact of different soil media on growth and chemical constituents of *Jatropha curcas* L. seedlings grown under water regime in Egypt. They investigated the influence of some soil media (sand, clay and sand and clay) under different water regimes (500, 1000, 1500 and 2000 cm3/pot) on growth and chemical constituents of *Jatropha curcas* L. Their results showed that, increasing water supply gradually increased significantly plant height, stem diameter, number of leaves/plant, leaf area, fresh and dry weight of leaves and stem. They noticed same behavior concerning chlorophyll a, b, a and b, carotenoids content as well as N, P and k uptake in shoots. However, the root length, fresh and dry weight of roots as well as N, P, K and proline content increased as water level decreased. Also, they observed that all growth parameters, three pigments content, N, P, K and proline content tended to increase by using clay media followed by sand and clay media as compared with sand media. Therefore, they concluded that Clay media can be used to reduce the effect of water stress up to 500 cm3/pot and these applications may be recommended for overcoming the harmful effect on growth and chemical constituents of *Jatropha curca* L. Seedlings under water stress.

Hofelena and Martinez (n.d.) studied the growth performance of two types of planting materials of *Jatropha curcas* namely: seeds and cuttings in different soil media in Philippines. They used limited to pure garden soil (So); garden soil and sand (S1); garden soil and sand and chicken manure (S2); garden soil and sawdust (S3); garden soil and sawdust and chicken manure (S4); garden soil and rice hull (S5); garden soil and rice hull and chicken manure (S6) as the soil media. They determined which of the planting materials and soil media influence growth performance of Jatropha. The growth performance was measured in terms of germination and sprouting, plant height, stem diameter, root length, root volume and survival. After three months, the study concluded that seedlings performed better than cuttings in terms of plant height, root length, root volume and survival. Among the soil media, garden soil and sand and chicken manure (S2) and garden soil and rice hull and chicken manure (S6) showed better performance - taller plants with bigger stems.

2.5.6 Uses of Jatropha

Presently, the most important use of Jatropha is the use of its oil as bio- diesel after trans-esterification. The diesel produced from Jatropha is environmentally friendly, renewable, has low sulphur emission and provides energy and green house balance (Duke, 1983, cited Abubakar, 2010). Jatropha is environmentally superior to petroleum diesel because it emits about two third (2/3) less unburned hydrocarbons and it contains little or no sulphur (Giri- Rao, 2007, cited Abubakar, 2010).

With the present interest in the energy-producing potential of Jatropha, it is useful to look at the attributes, both positive and negative of the plant, and to compare the relative energy values of its different part. It is interesting to note that the energy content of the remaining parts of the fruit after oil extraction exceeds the energy content of the oil.

Jatropha has proven effective in reducing the erosion of soil by rainwater. The taproot anchors the plant in the ground while the profusion of lateral and adventitious roots near the surface binds the soil and keeps it from being washed out by heavy rains. Jatropha also improves rainwater infiltration when planted in lines to form contour bunds. Furthermore, Jatropha hedges reduce wind erosion by lessening wind velocity and binding the soil with their surface roots (Henning, 2004a cited FAO, 2010).

However, these anti-erosion effects are limited by dry season leaf drop. This means there is less protection at a time when wind erosion is highest and there is no leaf canopy to protect the soil when the first heavy rains fall. This can be ameliorated by growing drought-resistant ground cover plants such as agave.

In many tropical and subtropical countries, Jatropha cuttings are planted as a hedge to protect gardens and fields from wandering animals. Livestock will not eat the mature leaves and even goats will die of starvation if there is only Jatropha to browse (Henning, 2004a cited FAO, 2010). For the same reason, Jatropha is often planted to mark homestead boundaries. Hedges planted very close together (5 cm) form a barrier that is impenetrable even by chickens.

The wood of Jatropha is soft and hollow and, contrary to some reports in the literature, is not good fuelwood. Jatropha groves on the islands of Cape Verde have been used as a fuelwood source, mainly due to the lack of other suitable species.

Jatropha is grown as a support and shade tree in smallholder vanilla farms in Madagascar and Uganda. The tree stems are pruned while the canopy is left to provide shade. As a result, vanilla plantations report low Jatropha seed yields of around 200 kg per ha (Henning, 2004a cited FAO, 2010).

Jatropha trees grown from seed develop taproots. Thus, they are able to extract minerals that have leached down through the soil profile and return them to the surface through leaf fall, fruit debris and other organic remains. In this way, Jatropha acts as a nutrient pump which helps rehabilitate degraded land.

Jatropha plant extracts have many uses in traditional societies (Heller, 1996 cited FAO, 2010). The dried latex resembles shellac and is used as a marking ink. The leaves and bark are used for dyeing cloth.

Jatropha has medicinal qualities, including a blood coagulating agent and antimicrobial properties that are widely used in traditional medicine and for veterinary use. All parts of the plant are used. Some of these uses that are briefly described below are to some extent anecdotal.

The latex has a widespread reputation for healing wounds and stopping bleeding, and for curing various skin problems. It is used against pain and the stings of bees and wasps. The fresh stems are used as chewing sticks to strengthen gums and treat gum disease (Heller, 1996 cited FAO, 2010).

The bark has a purgative effect similar to that of the seeds. In the Philippines, fishermen use the bark to prepare a fish poison. The dried and pulverized root bark is made into poultices and taken internally to expel worms and to treat jaundice. A decoction of the roots is used to treat diarrhea and gonorrhoea.

The leaves also have a purgative effect. Applied to wounds and in decoction, they are used against malaria and to treat hypertension. The leaf sap is used externally to treat haemorrhoids. A hot water extract of the leaves is taken orally to accelerate secretion of milk in women after childbirth. A decoction is used against cough and as an antiseptic following childbirth (Heller, 1996 cited FAO, 2010).

The oil-rich seeds and seed oil are used as a purgative and to expel internal parasites. The oil is applied internally and externally to induce abortion, and externally to treat rheumatic conditions and a variety of skin infections. The oil is also an ingredient in hair conditioners.

Besides the current interest in the use of the seed oil for biofuel, it is also used for making soap on a small scale and for illumination. In China, the oil is boiled with iron oxide and used to produce furniture varnish. Extracts of the seed oil have been found effective against a number of crop pests and snail vectors of schistosomiasis (Heller, 1996 cited FAO, 2010).

Jatropha has the potential to generate rural employment, reclaim waste land, earn foreign exchange, facilitate the establishment of rural based agro- industries, improve the socio-economy of rural dwellers and lead to overall development of Nigeria because of its numerous uses (Heller, 1996 cited FAO, 2010).

2.6 The Effects of Microclimatic Conditions on *Jatropha curcas* Seedlings

Ndiaye *et al.* (2008) studied seed germination, growth rate, propagation by seeds and cuttings and micro propagation of *Jatropha curcas* in green house conditions and in the fields in Senegal. They found out that percentage germination under green house conditions was 86% and the In vitro germination was difficult to achieve due to seed infections while coatless seeds allowed only 20% germination. The three month old seedlings reached a mean height growth of 24.3cm. The overall survival of seedlings in Ndiol station was 99.4% for planted seedlings and 60% for cuttings four weeks after planting.

Jatropha grows wild in south east Rajasthan which lies on south east side of Aravalli hill range which roughly divides the state in semi-arid and arid regions. A detailed survey was carried out in these areas. Nursery techniques for large scale plantation of elite strains have been developed. An area of 35 ha has been planted with *Jatropha curcas* with the high yielding strains identified during the course of investigation. The morphological parameters have been employed to characterize initial growth of the plants in the nursery stage. The plants showing improved growth at the nursery stage in terms of stem girth and plant height had positive correlation on its further growth some of the plants in their second year of growth have shown flowering and fruiting during months of September to January. Application of fertilizers and proper irrigation schedule has improved the growth and productivity of plants (Kumar, 2009).

Adeoye, *et. al.*, (2011) investigated the effect of tree canopy on the growth of *Jatropha curcas* seedlings in South Western Nigeria. In the study, 15 seedlings were placed under Gmelina, 15 seedlings under *Bambussa vulgaris* and 15 seedlings in an open space as a control; they observed stem height, diameter and leaf count for a period of 12 weeks with 8 weeks of thorough observation, measurements and record of data. Their result shows that seedlings placed under *Bambussa vulgaris* canopy gave the best performance in term of leaf count and stem diameter while seedling placed in the open space gave the best performance in terms of stem height. They finally recommended that for proper growing of *Jatropha curcas* seedlings, seedlings should be raised under *Bambussa vulgaris* canopy as this will provide a modulating effect on the micro climatic condition under which the growth condition of *Jatropha curcas* seedlings can be modified and improved naturally.

CHAPTER THREE: THE STUDY AREA AND METHODOLOGY

3.1 Introduction

This chapter comprises of the study area (Kano, Nigeria) and the methods (methodology) that were employed for the collection and analysis of the data for this study.

3.2 The Study Area

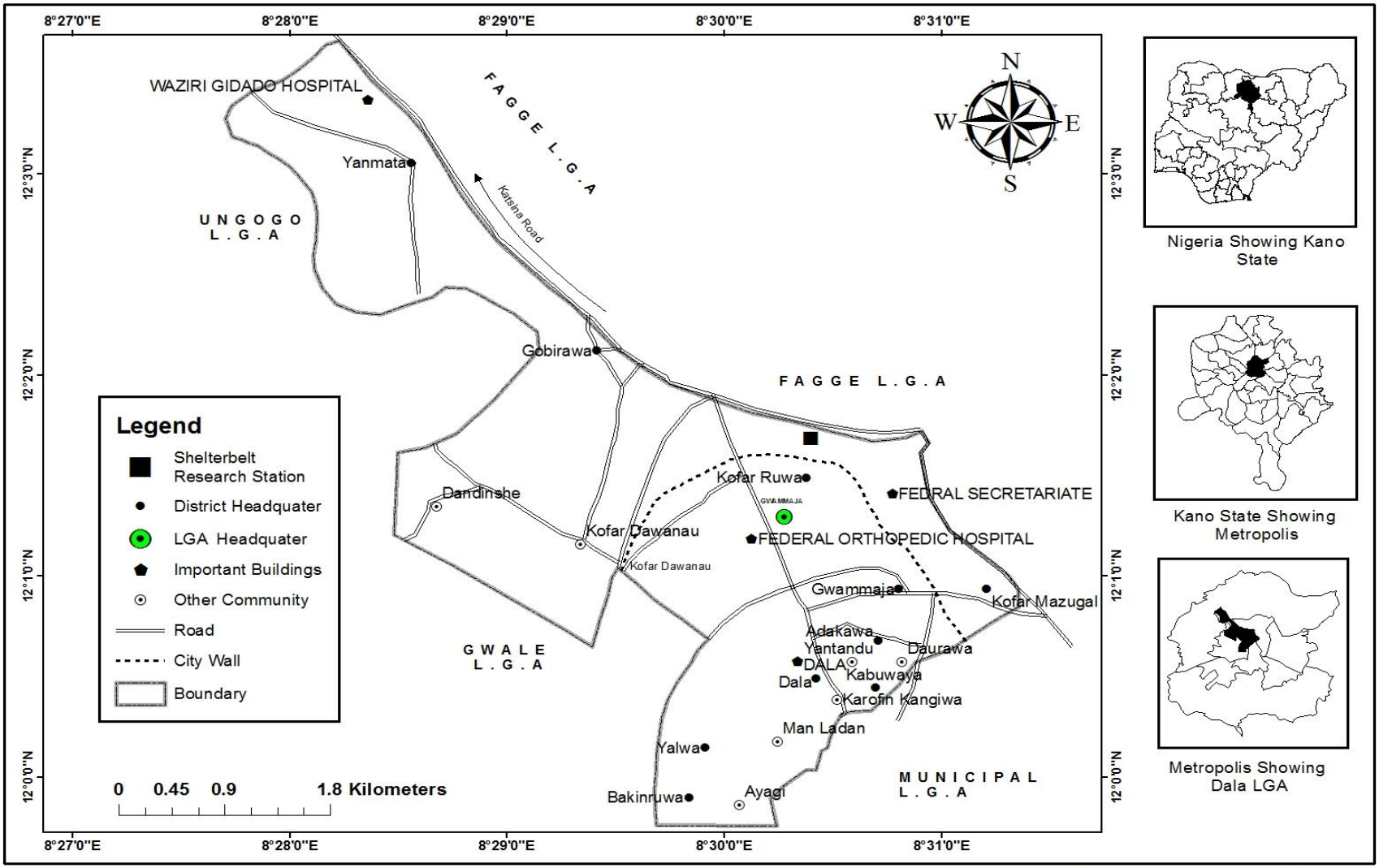
This subsection considered only major physical environmental elements that are important to this type of study.

3.2.1 Location of Experimental site

The experimental site is Forestry Research Institute of Nigeria (FRIN) Shelterbelt Research Station, Katsina road, Kano. It is situated at Katsina road opposite Bukavu Army Barracks, Dala Local Government area of Kano State. The Station lies between latitude $12^0 1\square 42.20\square\ \square$and $12^0 1\square 43.65\square\square$ north of the equator and between longitude $8^0 30\square 19.06\square\ \square$ and $8^0\ 30\square 29.07\square\ \square$east of the prime meridian. It is bounded by Federal Department of Forestry to the east, Wood market to the west, Katsina road to the north and ancient Kano city wall to the south (See Figure 3.1).

3.2.2 Climate

The climate is the tropical wet and dry type coded as Aw based on the Koppen's classification of climate. Rainfall is a very critical element in this area because of its deficiency during the dry season. The wet season lasts for 4-5 months (May to September), with a mean annual rainfall of about 884mm. Temperature ranges from 21^oC in the coldest months (December/January) to 31^oC in the hottest months April/March). Four distinct seasons are experienced, which are the dry and cool, dry and hot, wet and warm, and dry and warm seasons (Olofin, 1987; & Olofin, 2013).



Source:Cartography Lab Geography Department B.U.K (2015)

Figure 3.1 Dala Local Government Area Showing the Experimental Site

The seasons are determined by the movement of two air masses, a moist rather cool southerly mass known as south-westerlies and a hot and dry northern air called the north-easterlies. The moist southern air forms a wedge under the lighter dry air and the region where the two air masses meet is primarily an area of pronounced moisture gradient. The humidity gradient is called the intertropical discontinuity (ITD) (Olofin, 1987).

The annual motion of the ITD is northwards between February and August and southwards between September and January. The north-south movement of the ITD influences weather pattern. Maximum rainfall is recorded in an area of considerable disturbance (air movement) 8^{o} to 9^{o} southwards of the ITD. However, when disturbance is limited or when the northward movement of the ITD is restricted drought is recorded. The level of disturbance and the northward movement of the ITD are influenced by the global pattern of pressure and winds as well as the interaction of the surface air and the upper air mass (the jet streams). When the ITD is southwards, the state is under the north easterlies and there is weather change. The weather changes arising from the movement of the ITD gives the four seasons (Olofin, 1987).

a) ***Hot and dry season* (*Rani*)**

The ITD starts its southward movement in February and between March and May it has no considerable influence in the state and the weather is hot and dry during *rani* season. The mean temperature is 28^{o}c to 30^{o}c while this is the season when the "false" start of the rain is recorded in May. A few rainfall instances are recorded in May and rain days are separated by days of dry spell and less than 1% of the annual rainfall is recorded in May (Olofin, 1987).

b) ***Warm and wet season* (*Damina*)**

The ITD has by now made considerable advance northward and there is widespread rainfall in the state. Rainfall occurs mainly in the evenings for periods of one to three hours and

considerable heavy rainfall (high intensity) is recorded in the first forty minutes of rainfall occurrences. Over 90% of the annual rainfall is recorded in this season. This is the humid period when surface runoff is available for stream flow and soil moisture in sufficient for plant growth. *Damina* is the crop growing season when grains and legume are grown. Temperature drops to an average of 24^{o}C to 29^{o}C while evaporation is lower because of the higher relative humidity of the moist south westerlies air. This is why the runoff-coefficient is highest during this season (Olofin, 1987).

c) ***Warm and dry season* (*Kaka*)**

The ITD is now in its southward retreat and only a few showers may be recorded in October accounting for less than 8% of the annual rainfall. This is the harvest season between October and November when farmers are busy harvesting crops and traders are buying what is offered. Average temperature is 28^{o}-29^{o}C and this is a dry season as evaporation is in excess of rainfall. This is a season when soil moisture is depleted and stream flow recedes (Olofin, 1987).

d) ***Cool and dry season* (*Bazara*)**

The ITD reaches its southern limit during this season and the state is under the influence of the north easterly wind which brings a cool and dusty weather called 'Harmattan" between December and February, the dry air from the north brings no rainfall but the transported harmattan dust is deposited to replenish soil nutrient. The depth of the wind rift material varies from an average of 1m to 2m. This is the cool season when temperature is 25^{o} to 27^{o}C (Olofin, 1987; & Olofin, 2013).

Air humidity is high during the wet season and very low during the dry season. The evaporation data recorded and analyzed by standard class "A" pan was estimated at 2214mm per annum and the potential evaporation in Kano was estimated at 2538mm per annum (Olofin, 1987). The vapour pressure (eP) is at its maximum point between May and August with the range of 25-28 hecto- pascal (Hp), with the lowest recorded in March which is 7Hp. The dew point is less than 1°C in March and rise up to 23°C in August; this factor explains the water condition in the area. The potential evapo-transpiration exceeding rainfall changes in vapour pressure records and steady rise in dew point between April and August emphasized the dry condition of the area. Humidity is largely influenced by the movement of the Inter Tropical Discontinuity (ITD). Humidity is high under the influence of tropical maritime air mass (mT), during the rainy season. It can rise up to 90 percent and sometimes as low as 20 percent in the harmattan season between November and March (Olofin, 1987).

3.2.3 Soil and Vegetation

In their natural state, the soils divide into four main groups. The ferruginous tropical soils formed on crystalline acid rocks occupy about two fifth of the State to the south, southwest and south east; the brown and reddish brown soils and latosols occur in the northern half; the brown and reddish soils are in the northeastern corner; and the juvenile and hydromorphic soils occur along the alluvial channel complexes. The soil is of tropical ferruginous type, which is rich in iron, mostly originated from wind-drift materials overlaying the parent rock. Generally, the soil is rich, thus, having the potential to support variety of crops, most importantly cereals and legumes. The soils largely reflect the influence of parent materials. Intensive use of the soils and addition of manure and chemical fertilizers have altered their character, profile, texture, structure and chemical characteristics. The zonal soils are the ferruginous tropical soils whole equivalent is nitrosols (FAO), Ultisols and Altisole (US Dept of Agric) and Latosols (General). They are the normal product of soil development on the acid crystalline rock. The soils have marked differentiation of horizons, frequently has a leached A horizon and always contain a textual or structural B horizon (Olofin, 1987; & Olofin, 2013).

The soil has appreciable reserves of weatherable minerals with moderately low CEC. Clay is mainly kaolinite but small amounts of illite may be present. Free iron oxides may form mottles and concretions. Differences from the dominant characteristics are attributed to other soil forming factors. For example, in the dry areas where there is appreciable amount of sand drift, there is, developed, what is known as the brown and reddish brown soils of semi arid areas (Olofin, 1987; & Olofin, 2013).

The brown and reddish brown soils are called Xerosols (FAO, UNESCO), and Aridisols (US Dept of Agriculture). The soil exhibit profile development heaving a textural, structural or

colour B horizon. There is considerable reserve of minerals due to the slight weathering and leaching arising from low rainfall (Olofin, 1987; & Olofin, 2013).

Time factor is also important and there are juvenile soils with very weak or no definition of genetic horizons because of the young age of the soils. There are two subdivisions of juvenile soils due to the nature of the parent rock. There are those on riverine and lacustive alluvium as well as those on aeolian sands. There are more extensive areas of alluvial soils in valley bottoms and floodplains. These soils are varied in their texture and drainage characteristics. Site factor is important because on steep slope, erosion and mass movement limit soil development. In this case the weakly developed soils are called lithosols. On poorly drained sites one finds hydromorphic soils. These are in concave slope segments; the mineral soils exhibit no profile development. They are vertisol soils, which show deep and wide cracks in the dry season due to high content of clay (more than 30%) (Olofin, 1987; & Olofin, 2013).

The natural vegetation is the Sudan Savannah type, which is gradually being replaced by cultural vegetation in the form of cultivated fields known as farmed parkland (Olofin, 1987), dotted with patches of shrub savannah. The savannah woodland, which is the second largest zone, is typified by the Falgore Game Reserve. There are few forest plantations of exotic trees.

Savannah vegetation is simply described as closed grass or other predominantly herbaceous vegetation with scattered or widely spaced woody plants. The climatically defined vegetation types in the state are the northern Guinea savannah and Sudan savannah. Northern Guinea Savannah is an open woodland or bush land with grasses shorter than in the southern guinea where grasses are 1.5m to 3m tall. The Sudan Savannah has scattered trees in open grassland with grasses under 1.2m tall (Olofin, 1987; & Olofin, 2013).

The vegetation has been largely cleared for cultivation to form cultivated parkland. Parkland has scattered protected trees at some distance apart in open cultivated land. Small trees and shrubs are more common on fallow land where regeneration may take place. About 75% of

the land is cultivated parkland with average tree densities of less than 25 per hectare (Olofin, 1987; & Olofin, 2013).

Within the two broad types of vegetation identified, there are pockets of other structural types. Thicket vegetation is found along large river channels and floodplains and it is described as impenetrable shrubby vegetation. Surviving savannah woodland is found as forest/game reserve such as the Falgore reserve ($370km^2$) (Olofin, 1987; & Olofin, 2013).

Varieties of species such as *Parkia clappertoniana (Dorawa)*, *Tamarindus indica (Tsamiya)*, *Azadirachta indica (Darbejiya)*, *Acacia albida (Gawo)*, *Acacia seyal (Dushe)* are found in Kano. Other associated plant species include *Acacia nilotica (Bagaruwa)*, *Acacia senegal (Dakwara)*, *Balanites aegyptiaca (Aduwa)*, *Ziziphus spina-christi (Kurna)*, and *Anogeissus leiocarpus (Marke)* (Ahmed, 2011).

3.3 Methodology

This subsection discussed the methods used for the collection and analysis of data.

3.3.1 Reconnaissance Survey

A reconnaissance survey was carried out on Thursday 20 March 2014 before the commencement of the experiment. It was carried out in order to acquaint the researcher with the study area. Other activities carried out during this preliminary survey include site selection and identification of suitable instruments that were used in the experimental study.

3.3.2 Types of Data

The types of data generated in order to achieve the set objectives include:

i. Microclimatic conditions (air temperature, relative humidity and dew) of the *Jatropha curcas* seedlings in the two experimental treatments.

ii. Early growth characteristics (days to emergence, plant height, stem diameter, leaf area, number of leaves per plant, fresh weight per plant, dry weight per plant and crop growth rate (CGR) per plant) of the *Jatropha curcas* seedlings in the two experimental treatments.

These early growth characteristics were selected based on the knowledge that they are the most common plants' early growth parameters investigated in agronomic researches (for example Nnka, 2011; Adamu, 2014; & Mustapha, 2014).

3.3.3 Sources of Data

The data for this study were obtained from both primary and secondary sources.

3.3.3.1 Primary Sources

The primary sources of data include the daily measurement of air temperature, relative humidity and dew using two Lascar EL- USB Temperature/Relative Humidity data loggers, one for each of the treatments. While data on the early growth characters of *Jatropha curcas* seedlings from the two treatments were sourced from Field/ Nursery work.

3.3.3.2 Secondary Sources

The secondary sources which were only used as sources of literature were obtained from maps, journals, conference papers, publications, textbooks, research thesis, documents and materials from related websites, information from Institute of Agricultural Research (IAR) Zaria and other related Research Institutes of Nigeria.

3.3.4 Treatments and Experimental Design

The treatments consisted of two micro climatic conditions (Shade and Sun).There were 90 polyethene pots all together with 45 polythene pots placed under tree shade (T1) and 45 polyethene pots placed in an open space (in the Sun) (T2). The experiment was laid out in a completely randomized design (CRD) with six repetitions.

3.3.5 Detailed Field/ Nursery Work

Two Lascar EL- USB Temperature/Relative Humidity Data Loggers, one for each of the treatments were programmed to sample air temperature, relative humidity and dew at every six hours. The instruments were raised 1.2m above the ground at each of the two treatments. The instruments measure and record temperature readings using internal sensor or external thermocouple, and it has a direct USB connection, user programmable alarms for high and low thresholds. It also has software for setup, data download and analysis, and a frequency of 1 second to 12 hours sampling rate. The sensor has 94% accuracy (Equipment-professional, 2012).

Similarly, Fresh untreated *Jatropha curcas* seeds were collected from Shelterbelt Research Station, Kano. Two seeds per pot were sowed at 2cm depth directly in to 10 x 20cm polythene pots containing potting mixture of sand, soil and cow dung in the ratio of 1:1:2 by volume which were later thinned to one seedling at two weeks after sowing (2 WAS) as recommended by (Abubakar, 2010). The seedlings were irrigated in the morning on daily basis. The early growth characteristics (Number of days to seedlings' emergence, plant height, stem diameter, leaf area, number of leaves per plant, fresh weight per plant, dry weight per plant and crop growth rate (CGR) per plant) were also measured as follows:

i. Number of days to seedling emergence was recorded from the date of sowing to when the final seedling emerges for each of the two treatments.

ii. Plant height was determined from five tagged plants at 2, 4, 6, 8, 10 and 12 weeks after sowing. Each plant was measured from its base to the terminal bud using a meter rule and the average was taken and recorded.

iii. Stem diameter was measured from five tagged plants at 2, 4, 6, 8, 10 and 12 weeks after sowing using a digital vernier caliper. Each plant was measured at 2cm from its base and the mean was obtained and recorded.

iv. Leaf area was measured using leaf area meter at 2, 4, 6, 8, 10 and 12 weeks after sowing and the average was obtained and recorded.

v. Number of leaves per plant was determined by counting the number of leaves of five tagged plants and dividing the total number by five at 2, 4, 6, 8, 10 and 12 weeks after sowing.

vi. Fresh weight of whole plant per plant was determined by uprooting five sampled plants and weighed using an electronic weighing balance (ADP 3100L) at 2, 4, 6, 8, 10 and 12 weeks after sowing. The total weight was later divided by five to obtain the mean.

vii. Dry weight of whole plant per plant was determined using an electronic weighing balance (ADP 3100L) after oven drying the above five sampled plants at 70^{o} C to a constant weight at 2, 4, 6, 8, 10 and 12 weeks after sowing and the mean was recorded.

viii. Crop growth rate (CGR) is the net gain in dry weight per unit time (between two observations) per unit ground area. It was calculated using data from dry matter

production at 2, 4, 6, 8, 10 and 12 weeks after sowing, using the formula given by Watson (1958).

$$CGR = \frac{W_2 - W_1}{T_2 - T_1} \text{ (g/ m}^2\text{ / week)}$$

Where: W_1 and W_2 represent dry weights in grams at times T_1 and T_2 respectively.

Plates 3.1- 3.6 below shows the experimental treatments and some of the methods used during data collection.



Plate 3.1 Seedlings in the Sun at Eight (8) WAS With a Data Logger Attached on a Pipe



Plate 3.2 Seedlings in the Shade at Eight (8) WAS With a Data Logger Attached on a Tree



Plate 3.3 Measurement of Seedlings' Height Using a Meter Rule



Plate 3.4 Measurement of Seedlings' Stem Diameter Using Digital Vernier Caliper



Plate 3.5 Measurement of Seedlings' Leaf Area Using a Digital Leaf Area Meter



Plate 3.6 Measurement of Seedlings' Fresh Weight Using Digital Weighing Machine

3.3.6 Methods of Data Analysis

The microclimatic conditions (air temperature, relative humidity and dew) were measured and recorded by two lascar EL- USB Temperature/Relative Humidity Data Loggers, one for each of the treatment which were mounted at 1.2m above the two experimental treatments for a period of three months (12 weeks) that is from 20 April, 2014 to 14 July, 2014. A total of three hundred and forty one (341) values were measured and recorded which were down loaded from the data loggers to the computer and summarized into six (6) mean two weeks values, that is computing the mean air temperature, relative humidity and dew at 2, 4, 6, 8, 10 and 12 weeks after sowing the *Jatropha curcas* seeds in the two experimental treatments. This was done, in order to make the microclimatic conditions raw data to correspond with the early growth characteristics data which were generated at 2, 4, 6, 8, 10 and 12 weeks after sowing. Both descriptive and inferential statistical techniques were employed for the data analysis.

3.3.6.1 Determination of the microclimatic conditions and the early growth characteristics of Jatropha curcas seedlings

Line and bar graphs were used to present the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings at both the two experimental treatments.

3.3.6.2 Relationship between microclimatic conditions and the early growth characteristics of Jatropha curcas seedlings

Statistical Package for Social Science (SPSS) was used to compute Pearson' product moment correlation using partial method in order to examine the relationship between the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the two experimental treatments. The first hypothesis was tested at 95% level of significance.

3.3.6.3 Difference in the microclimatic conditions and the early growth characteristics of the Jatropha curcas seedlings

Statistical Package for Social Science (SPSS) was used to compute paired student t- test in order to determine the difference in the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings between the two experimental treatments. The second hypothesis was tested at 95% level of significance.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents and discusses the findings of the study on the effects of microclimatic conditions on the early growth of *Jatropha curcas* seedlings in Kano, Nigeria. The chapter is subdivided into sections and sub-sections. The division was based on the objectives of the study, hence the sections are: the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in shade and sun treatments, the relationship between the microclimatic conditions and the early growth characteristics of the *Jatropha curcas* seedlings in the two treatments; and the difference in microclimatic conditions and the early growth characteristics of the *Jatropha curcas* seedlings between the two treatments. Finally, the test of hypotheses were presented and discussed.

4.2 Microclimatic Conditions and the Early Growth Characteristics of *Jatropha curcas* Seedlings

This section is divided into two sub-sections. The first sub-section focused on the microclimatic conditions in the two treatments while the second looked at the early growth characteristics of *Jatropha curcas* seedlings in the two treatments.

4.2.1 Microclimatic Conditions

Microclimatic conditions of the shade and sun treatments were generated by data loggers. Temperature, Relative humidity and dew conditions were measured and the findings were discussed under sub-sections 4.2.1.1, 4.2.1.2 and 4.2.1.3

4.2.1.1 Temperature

The mean temperature recorded during the period of the experiment at the two treatments is presented in Figure 4.1

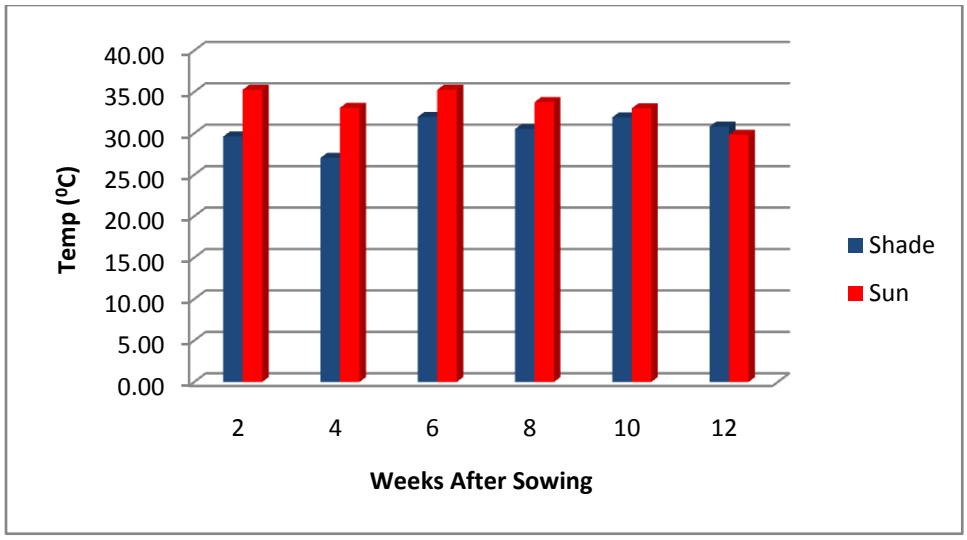


Figure 4.1 Mean Temperature in the Shade and Sun Treatments

It can be observed that the mean temperature values recorded in the sun treatment were higher than those recorded in the shade at 2, 4, 6, 8, and 10 Weeks After Sowing (WAS). It was highest at 6 WAS with a value of 35.29^{o}C while the lowest mean temperature recorded was in the shade at 4 WAS with a mean value of 27.05^{o}C. However, the mean temperature was slightly higher in the shade treatment at 12 WAS with a mean value of 30.83^{o}C and that of sun was 29.85^{o}C (Figure 4.1). The difference was 0.98^{o}C approximately 1^{o}C (see Appendix III).

This result portrays Kano as having high temperature, typically that of tropical climate as observed by Olofin (1987). The mean monthly temperature of the area is between 31 and 21^{o}C in the hottest and coolest month of the year respectively. The experiment was conducted during the hottest season hence the temperature recorded in the sun is a little above the mean of the hot season and that of the shade a little below. It is also not far from the results of Ibrahim, Nduka, Iguisi and Ati (2011) and Abdulhamed, Iguisi, Ati, Sawa and Nduka (2012) which revealed that the Sky View Factor (SVF) for Kano Metropolis ranges from 0.962 (NH) to 0.546 (BK) with a mean of 0.839 indicating that about 84% of the sky is visible, open and unobstructed by either vegetation or buildings, thus allowing a free flow of solar radiation in to and out of the land surface. This might be the reason for the difference in mean temperature between the sun and shade treatments.

4.2.1.2 Relative humidity

The mean relative humidity recorded during the period of this experiment at the two treatments is presented in Figure 4.2

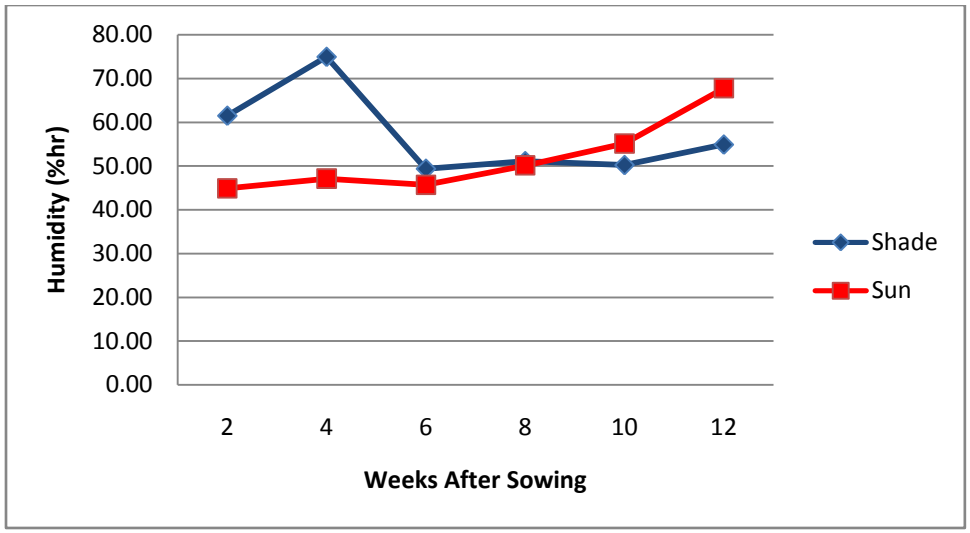


Figure 4.2 Mean Relative Humidity in the Shade and Sun Treatments

Figure 4.2 revealed that the mean relative humidity was higher in the shade at 2, 4, 6, 8 WAS. It was highest at 4 WAS with a mean value of 74.89% while the lowest was in the sun at 2 WAS with a mean value of 44.87%. However, the mean relative humidity was higher in the sun at 10 and 12 WAS with a mean values of 55.09% and 67.72% respectively, as against that of shade 50.16% and 54.84% respectively (see Appendix III). Unlike the case of temperature where sun treatments outshined the shade in most of the weeks, the relative humidity variation is difficult to explain. This can be explained by the fact that humidity is not a function of radiation alone but many factors (temperature, radiation, moisture availability and vapour pressure).

4.2.1.3 Dew

Figure 4.3 shows the mean dew recorded during the period of the experiment at both shade and sun treatments.

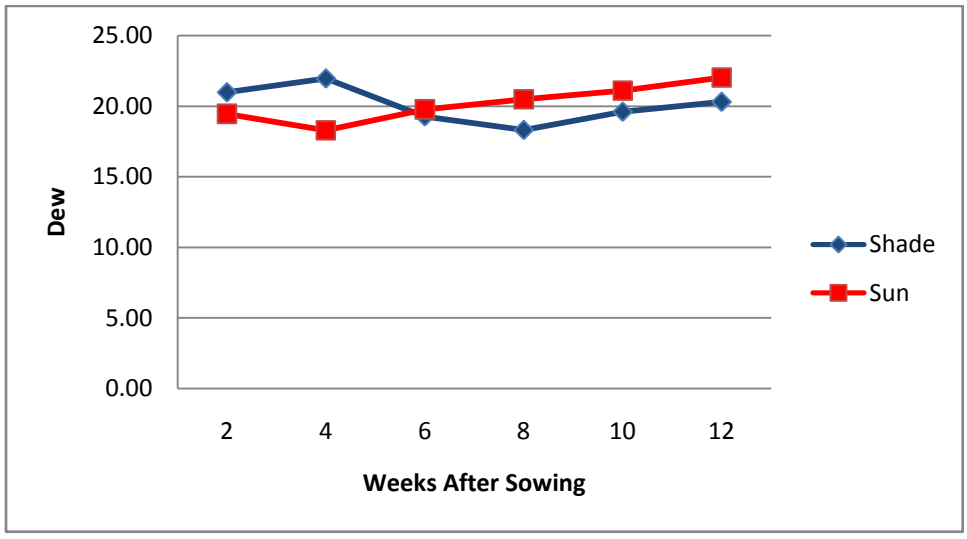


Figure 4.3 Mean Dew in the Shade and Sun Treatments

From Figure 4.3, it can be observed that the mean dew recorded in the sun was higher at 8, 10 and 12 WAS with mean values of 20.48, 21.09 and 22.02 respectively while there was a slight difference of 0.51 at 6 WAS between the shade and sun with the sun treatment being higher than its shade counterpart. However the mean dew in the shade was higher at 2 and 4 WAS with a mean value of 20.98 and 21.96 respectively (see Appendix III).

4.2.2. Early Growth Characteristics of *Jatropha curcas* Seedlings

This section presents and discusses the results of the early growth characteristic of *Jatropha curcas* seedlings generated through nursery work at the two experimental treatments (shade and sun) during the period of the experiment.

4.2.2.1 Number of days to seedlings emergence

The number of days taken by the seeds sown to emerge in the shade and sun treatments was examined here. The result is presented in figure 4.4.

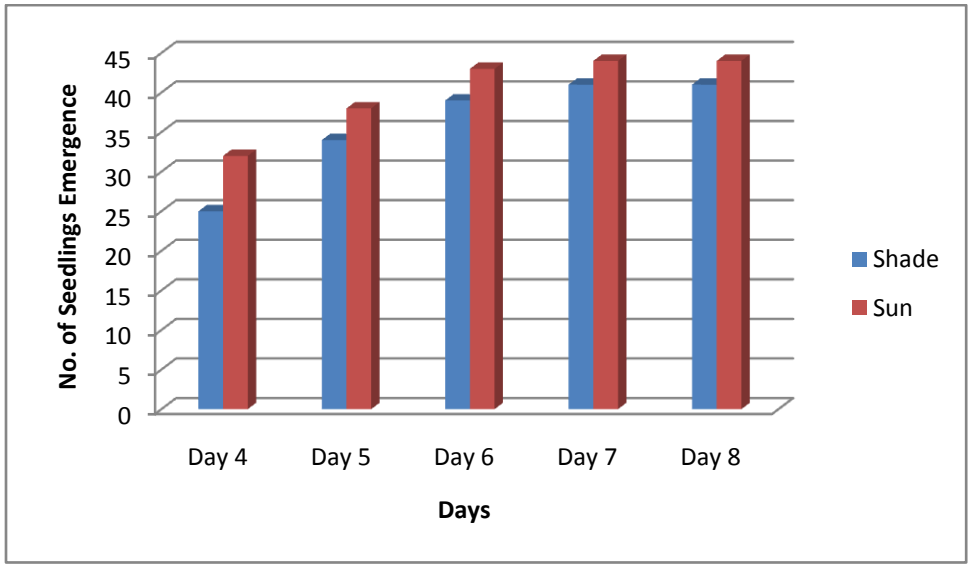


Figure 4.4 Number of Seedlings Emergence in the Shade and Sun Treatments

It can be observed that the seedlings emergence was first observed on the fourth day after sowing the seeds, where a total of 25 seedlings emerge in the shade while 32 seedlings emerge in the sun. The trend continued like that, with the seeds sown under sun having higher emergence up to the seventh and eighth day when a total and complete emergence was observed, with the

seeds sown in the shade having 41 seedlings and those in the sun with 44 seedlings (Figure 4.4). Therefore, seeds sown in the sun gave a better emergence of 98% while that of shade gave only 91% seedlings emergence. The remaining 2% and 9% seedlings in the sun and shade treatments respectively did not emerge, they eventually died. The high number of seedlings emergence in the sun can be attributed to high temperature observed in the sun treatment, temperature is most significant factor in seedling emergence.

This result is a break through because seedlings emergence was observed on the fourth day after sowing unlike previous studies that claimed the emergence of *Jatropha curcas* seedlings to starts from more than four days. For example Behera *et al* (2009) claims that *Jatropha curcas* seedlings emerges from 6 to 15 days or longer depending on temperature and moisture. Again, Abubakar (2010) also claims that pre- soaked seeds of *Jatropha curcas* in cold water for 24 hours will emerge within 7-8 days in hot humid weather.

However, seeds used for this experiment were not pre- soaked in cold water and yet emerges after four days of sowing. This implies that the viability of seeds plays a vital role in its germination and emergence, especially seeds from matured black or yellow fruits as recommended by Abubakar (2010).

Secondly, Ndiaye *et al.* (2008) conducted a study on seed germination, growth rate, propagation by seeds and cuttings and micro propagation of *Jatropha curcas* in green house conditions and in the fields in Senegal. They discovered that percentage germination under green house conditions was 86% and the In vitro germination was difficult to achieve due to seed infections while coatless seeds allowed only 20% germination. However, this study achieved a germination of 91% and 98% in the shade and sun conditions respectively, this is also a break through as it reveals that Farmers who cannot afford green house can sow their seeds in an open space (sun) or shade and still get a better germination results than those who used green house.

4.2.2.2 Plant height

This sub-section presents and discusses the results of the mean plants' height of seedlings in the shade and sun treatments during the period of the experiment. Figure 4.5 shows the result.

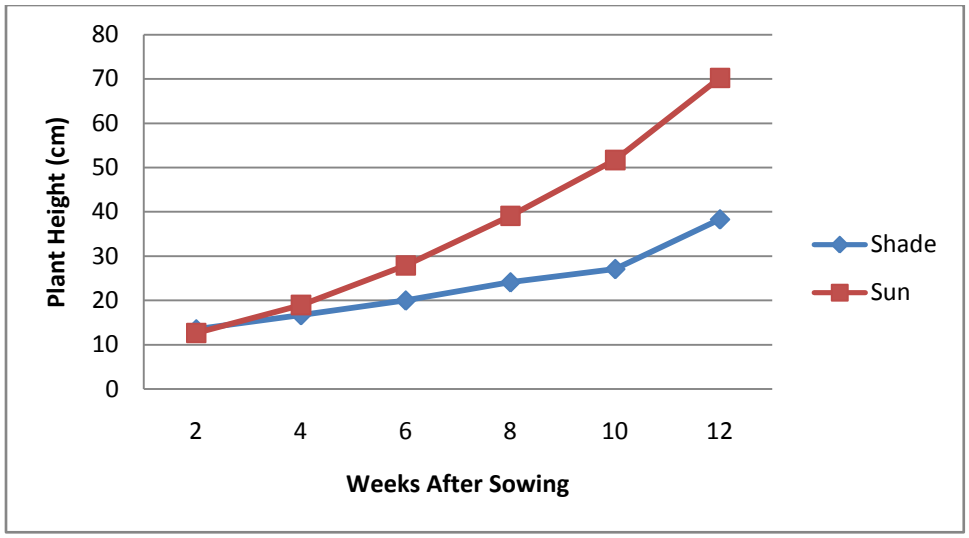


Figure 4.5 Mean Plant's Height in the Shade and Sun Treatments

From Figure 4.5, it can be observed that at the beginning of the experiment at 2 WAS seedlings in the shade have a higher mean plant height of 13.5cm while those in the sun have a mean plant height of 12.7cm but as number of days increase at 4, 6, 8, 10 and 12 weeks the seedlings in the sun grows faster than their shade counterparts reaching a mean height of 70.2m at 12 WAS.

However, the seedlings in the shade grow slowly reaching a mean height of only 38.3cm at 12 WAS (see Appendix V). Therefore, at the end of the experiment there was a difference in mean plant height value of 31.9cm between the seedlings in the shade and that of sun. The seedlings in the sun gave a better result in terms of plant height. This can be associated to high solar radiation intensity and temperature in the sun treatments. Growth is a product of chemical reactions, rate of reaction increases with increase in temperature.

This result corroborate that of Adeoye *et al*. (2011) in Ibadan southern Nigeria, their findings revealed that *Jatropha curcas* seedlings gave the best performance in terms of plant height in the open space that is in the sun. This result also gave a better performance in terms of mean plant height when compared with a mean plant height of 24.3cm at three month old obtained by Ndiaye *et al*. (2008) in Senegal because this study obtained a mean plant height of 38.3cm and 70.2cm at 12 WAS that is at three month old in the shade and sun treatments respectively.

4.2.2.3 Stem diameter

The result of the mean stem diameter of the seedlings in the shade and sun treatments is presented in figure 4.6.

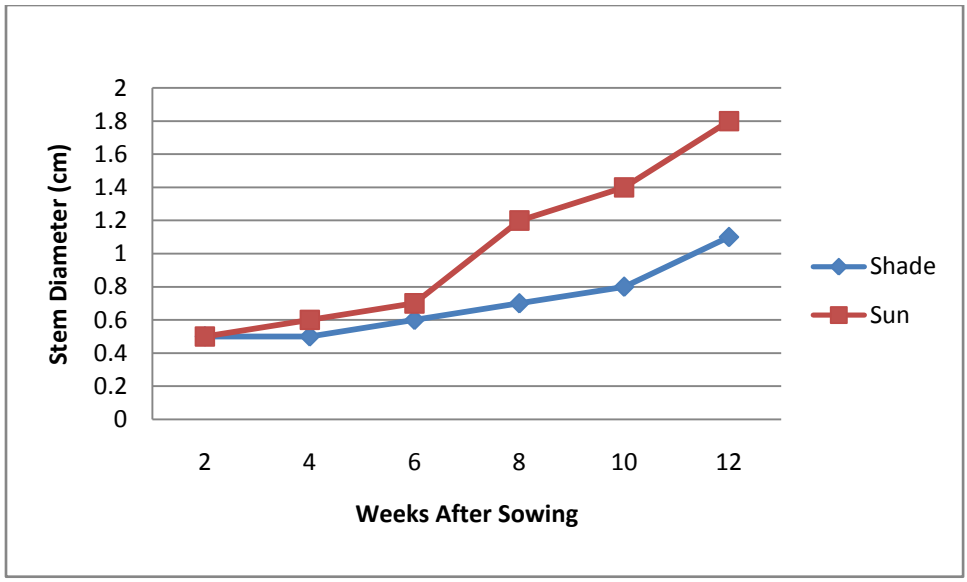


Figure 4.6 Mean Stem Diameter in the Shade and Sun Treatments

Figure 4.6 shows that at the beginning of the experiment at 2 WAS both seedlings in the shade and sun have same mean stem diameter of 0.5cm but as number of days increase, the stem diameter of the seedlings in the sun increases more rapidly than that of the seedlings in the shade. For example, at 4 WAS seedlings in the shade had same 0.5cm mean stem diameter while that of seedlings in the sun increases to 0.6cm. At the end of the experiment, that is12 WAS, seedlings in the sun have a mean stem diameter of 1.8cm while that of shade was only 1.1cm (see Appendix V). Therefore, the difference was 0.7cm at 12 WAS and this can be linked to high temperature and exposure to sun light in the sun treatment.

This results like that of mean plant height also shows that seedlings in the sun gave better results in terms of stem diameter. This however contradicts the findings of Adeoye *et al*. (2011) which found out that *Jatropha curcas* seedlings placed under *Bambussa vulgaris* canopy gave better performance in terms of stem diameter than their open spaced (in the sun) counterparts.

4.2.2.4 Leaf area

The result of the mean leaf area of the seedlings in the shade and sun treatments measured during the period of this experiment is presented in figure 4.7.

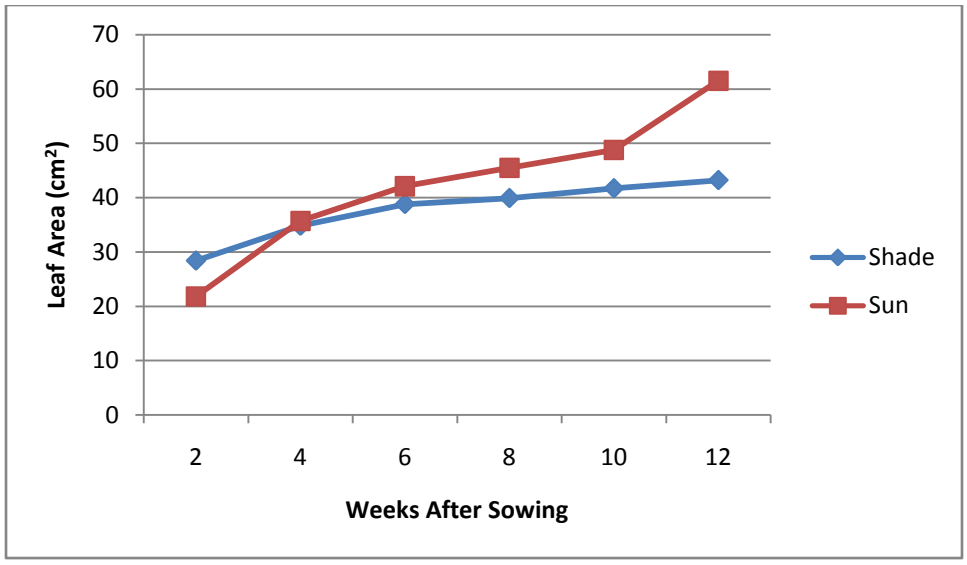


Figure 4.7 Mean Leaf Area in the Shade and Sun Treatments

It can be observed that seedlings in the shade at the beginning of the experiment, that is at 2 WAS have broader leaves with a mean value of 28.4cm^2 while that of sun was only 21.8cm^2 but later on, as number of days increase the leaves of the seedlings in the sun became broader than that of seedlings in the shade. At the termination of the experiment, that is at 12 WAS seedlings in the sun have a mean leaf area 61.5cm^2 while those in the shade have only 43.2cm^2 (see Appendix V). This result also shows that seedlings in the sun give a better result in terms of leave area. This can equally be linked to exposure to sun light and high temperature as in the case of height and stem diameter.

4.2.2.5 Leaf count

The number of leaves counted from the seedlings in the shade and sun treatments during the period of the experiment is shown in figure 4.8.

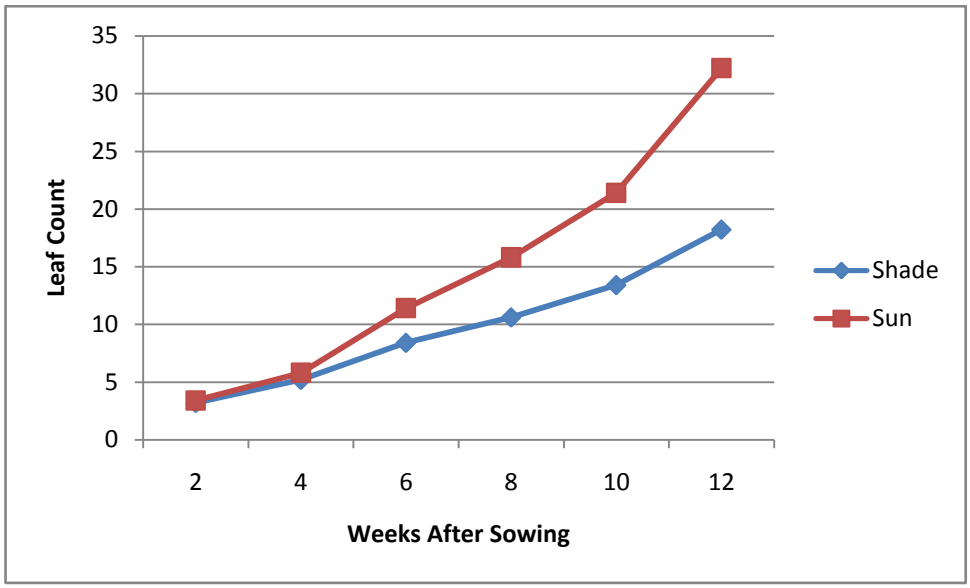


Figure 4.8 Mean Leaf Count in the Shade and Sun Treatments

The differences in mean number of leaves between seedlings in the shade and sun was not wide at the beginning of the experiment, that is at 2 WAS but the difference increase as number of days increase, it was 3.2 and 3.4 at 2 WAS in the shade and sun respectively, but at the end of the experiment, seedlings in the sun had 32.2 mean number of leaves while those in shade had only 18.2 mean number of leaves (figure 4.8).

This result shows that seedlings in the sun produce more leaves compared to their shade counterpart. This finding contradicts that of Adeoye, *et al*. (2011) which revealed that *Jatropha curcas* seedlings placed under *Bambussa vulgaris* canopy gave better performance in terms of leaf count than those in open area (in the sun).

4.2.2.6 Fresh weight

Mean fresh weight measured from the seedlings in the shade and sun treatments during the period of the experiment is presented in figure 4.9.

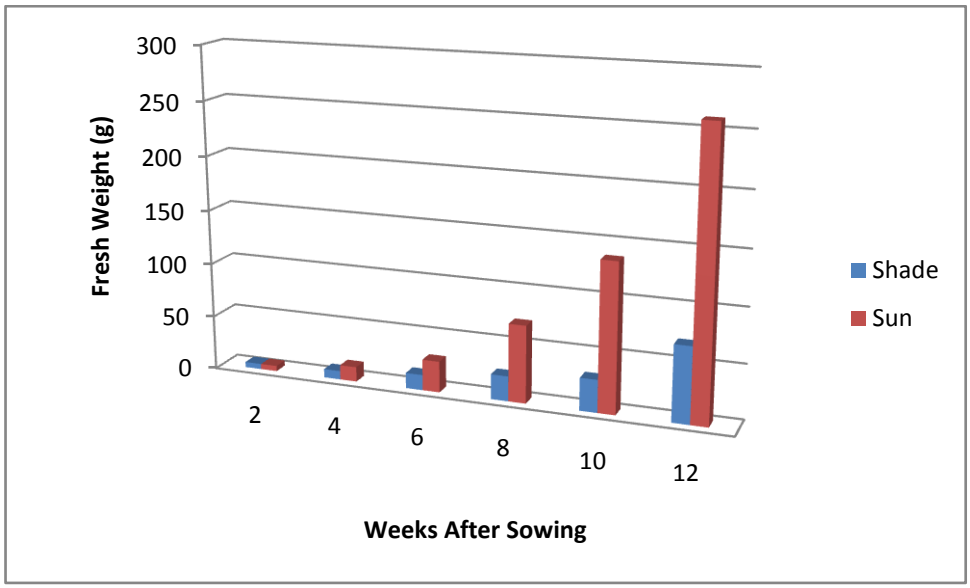


Figure 4.9 Mean Fresh Weight in the Shade and Sun Treatments

It can be observed that at the beginning of the experiment both seedlings in the shade and sun weigh 4.9g but later on as number of days increases the weight gain of seedlings in the sun increases rapidly while that of seedlings in the shade increases slowly there by giving a wide difference of 189.9g at the end of the experiment that is at 12 WAS, the seedlings in the sun weigh 259.6g while those in the shade weigh only 69.7g (figure 4.7, also see Appendix V).

This result shows that seedlings in the sun gave better results in terms of fresh weight than their shade counterparts. This is not surprising, having observed that *Jatropha curcas* seedlings in the sun performed better in all growth characteristics than their shade counterparts, hence likely to produce better, larger and more weighed seedlings.

4.2.2.7 Dry weight

Mean dry weights of the seedlings in the shade and sun measured during the period of this experiment is presented in figure 4.10.

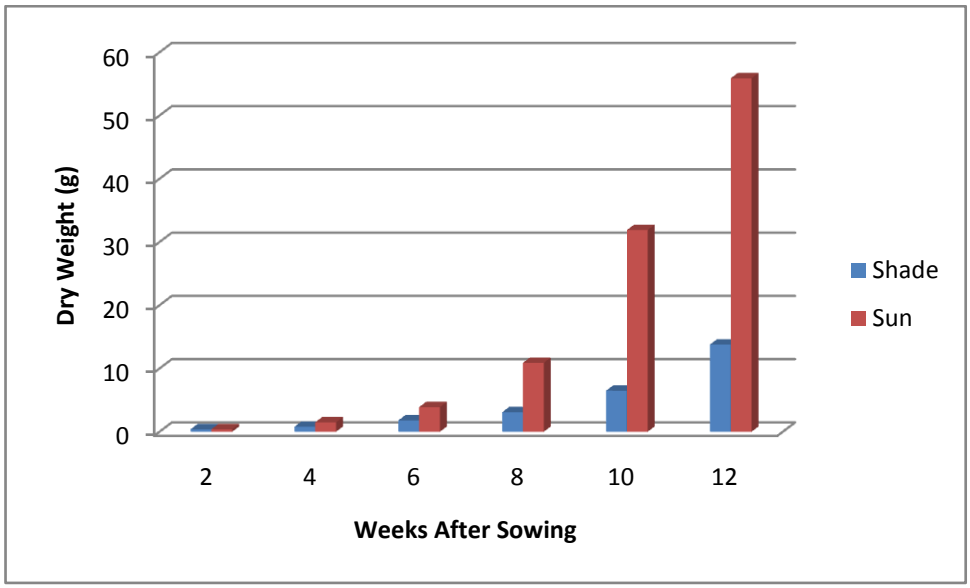


Figure 4.10 Mean Dry Weight in the Shade and Sun Treatments

From figure 4.10, it can be observed that like the fresh weight at the beginning of the experiment at 2 WAS, the dry weight of both the seedlings in the shade and sun was 0.4g but later on as number days increase, the dry weight of seedlings in the sun increases more rapidly than that of those in the shade. At the end of the experiment that is at 12 WAS the dry weight of the seedlings in the sun was 55.9g while that of shade seedlings was only 13.8g. This result shows that the dry weight of seedlings in the sun is higher than that of shade with a difference of 42.1g at 12 WAS (see Appendix V). This can be explained in the same way as fresh weight discussed in sub-section 4.2.2.6

4.2.2.8 Crop growth rate

This sub-section presents and discusses the results of the crop growth rates of the seedlings in the shade and sun during the period of the experiment. Figure 4.11 shows the result.

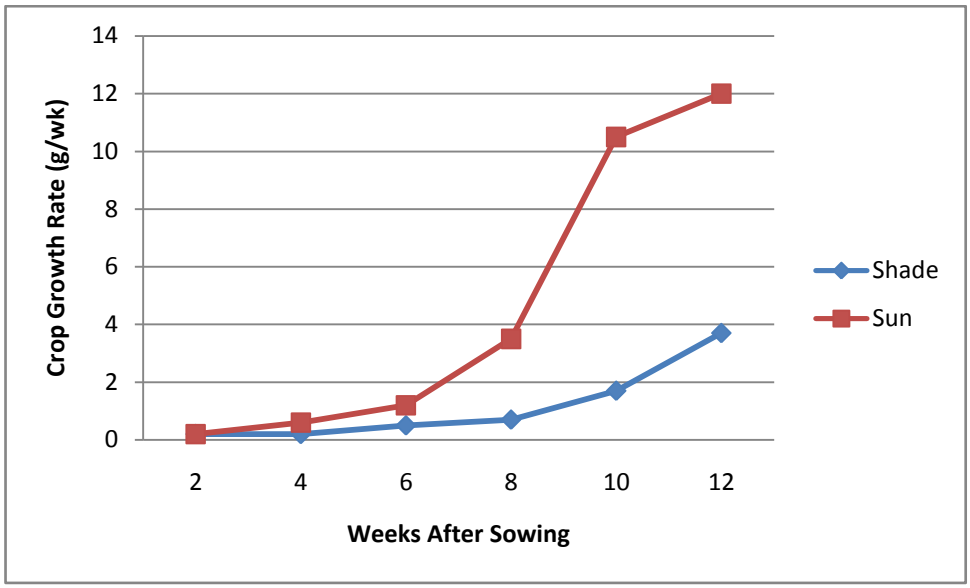


Figure 4.11 Mean Crop Growth Rate in the Shade and Sun Treatments

At the beginning of the experiment the crop growth rates of both the seedlings in the shade and sun was 0.2g/wk at 2 WAS but as number of days increase, the result tends to differ very much as the crop growth rate of the seedlings in the sun increases rapidly while that of the seedlings in the shade increases slowly reaching a weight of 0.7g/wk and 1.7g/wk at 8 and 10 WAS respectively (Figure 4.11). At the end of the experiment, that is at 12 WAS the crop growth rate of seedlings in the sun was found to be 12g/wk while that of the seedlings in the shade was only 3.7g/wk (see Appendix V). The difference was 8.3g/wk. Therefore, this result revealed that the crop growth rate of seedlings in the sun is higher than their shade counterparts.

These findings emphasized the importance of Sun light on plants generally; specifically, the results have revealed that *Jatropha curcas* plant is well adapted to high light intensity conditions and is unsuited to growing in shade. The findings are also not far from the findings of Baumgaart, (2007), cited Jongschaap, *et al*, (2007).

4.3 Relationship between the Microclimatic Conditions and the Early Growth Characteristics of *Jatropha curcas* Seedlings

This section compares microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the shade and sun treatments. The section is divided into two subsections, 4.3.1 and 4.3.2.

4.3.1 Relationship between Microclimatic Conditions and the Early Growth Characteristics of *Jatropha curcas* Seedlings in the Shade Treatment

This sub-section presents the result of the relationship between microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the shade treatment. It also

tests the first hypothesis of the study which presumed there is no significant relationship between the microclimatic conditions (air temperature, relative humidity and dew) and the early growth characteristics of *Jatropha curcas* seedlings in both shade and sun treatments.

4.3.1.1 Number of days to seedlings emergence in the shade

Table 4.1 shows the relationship between microclimatic conditions and number of days to seedlings emergence in the shade treatment.

Table 4.1 Relationship between Microclimatic Conditions and Number of Days to Seedlings Emergence in the Shade Treatment

	Temp	**Humidity**	**Dew**
Seedling Emergence	0.602	-0.705	- 0.888*

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

It can be deduced that there is a significant relationship between dew and number of days to seedlings emergence ('r' value = - 0.888*) at 0.05 significant level (Table 4.1). On the other hand, there is no significant relationship between the temperature and relative humidity and the number of days to seedlings emergence at both 0.05 and 0.01 significant levels. This result implies that there is an inverse relationship between the dew and seedlings emergence that is as the dew increases, the number of seedlings emergence decreases (see Appendix VI).

4.3.1.2 Early growth characteristics of Jatropha curcas seedlings in the shade

The result of the relationships between microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the shade treatment is presented in Table 4.2.

Table 4.2: Relationship between Microclimatic Conditions and the Early Growth Characteristics of *Jatropha curcas* Seedlings in the Shade Treatment

Jatropha Characteristics	**Temp**	**Humidity**	**Dew**
Height	*0.451*	*-0.458*	*-0.321*
Stem Diameter	*0.47*	*-0.467*	*-0.293*
Leaf Area	*0.55*	*-0.575*	*-0.548*
Leaf Count	*0.543*	*-0.548*	*-0.413*
Fresh Weight	*0.373*	*-0.367*	*-0.196*
Dry Weight	*0.384*	*-0.354*	*-0.146*
Crop Growth Rate	*0.380*	*-0.921*	*-0.115*

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

There is no significant relationship between microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the shade treatment at both 0.05 and 0.01 significant levels (table 4.2). However a general trend was observed from the table, in the sense that relationships between all the measured characteristics of *Jatropha curcas* and temperature are positive, and inverse between the characteristics and humidity and dew. Hence it can be deduced that increase in temperature is associated with increase in growth characteristics, however this relationship is not statistically significant in this study. Thus, the study did not contradict the general assumption that plant growth characteristics improve with temperature increase (see Appendix VII).

4.3.2 Relationship between Microclimatic Conditions and the Early Growth Characteristics of *Jatropha curcas* Seedlings in the Sun Treatment

The result of the relationship between microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the sun treatment is examined in sections 4.3.2.1 and 4.3.2.2. In addition, the sections tests the hypothesis that there is no significant relationship between the micro climatic conditions (air temperature, relative humidity and dew) and the early growth characteristics of *Jatropha curcas* seedlings in both shade and sun treatments.

4.3.2.1 Number of days to seedlings emergence in the sun

This sub-section presents and discusses the relationship between microclimatic conditions and the number of days to seedlings emergence in the sun treatment. The result is given in Table 4.3

Table 4.3 Relationship between Microclimatic Conditions and Number of Days to Seedlings Emergence in the Sun Treatment

	Temp	Humidity	Dew
Seedling Emergence	0.685	-0.718	- 0.943*

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.3 shows that there is a significant relationship between dew and number of days to seedlings emergence ('r' value = - 0.943*) at 0.05 significant level. On the other hand, there is no significant relationship between the temperature and relative humidity and the number of days to seedlings emergence at both 0.05 and 0.01 significant levels. This result implies that there is an inverse relationship between the dew and seedlings emergence as observed in the shade treatment (see Appendix VI).

4.3.2.2 Early growth characteristics of Jatropha curcas seedlings in the sun

The result of the relationship between microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the sun treatment is shown in table 4.4.

Table 4.4 Relationship between Microclimatic Conditions and the Early Growth Characteristics of *Jatropha curcas* Seedlings in the Sun Treatment

Jatropha Characteristics	Temp	Humidity	Dew
Height	*- 0.833**	*0.946***	*0.926***
Stem Diameter	*- 0.829**	*0.935***	*0.928***
Leaf Area	*-0.797*	*0.861**	*0.800*
Leaf Count	*- 0.831**	*0.951***	*0.931***
Fresh Weight	*- 0.896**	*0.992***	*0.904**
Dry Weight	*- 0.887**	*0.986***	*0.896**
Crop Growth Rate	*- 0.805**	*0.921***	*0.897**

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

From Table 4.4, it can be observed that there is significant relationship between microclimatic conditions and mean plant height. The relationship however, is more significant between mean plant height and mean relative humidity ('r' value = *0.946***) and dew ('r' value = *0.926***) than between mean temperature and mean plant height ('r' value = - *0.833**) which is an inverse relationship, that is an increase in one variable leads to the decrease in the other (see Appendix VIII).

The relationship between mean temperature and mean plant height is significant at only 0.05 significant levels while the relationship between mean plant height and mean relative humidity and dew is significant at both 0.05 and 0.01 significant levels. The mean stem diameter also have a significant relationship with the microclimatic conditions but the relationship is more significant between mean stem diameter and mean relative humidity ('r' value = *0.935***) and dew ('r' value = *0.928***) than between mean temperature and mean stem diameter ('r' value = - *0.829**) because the relationship between mean temperature and mean stem diameter is significant at 0.05 significant levels only while the relationship between mean stem diameter and mean relative humidity and mean dew is significant at both 0.05 and 0.01 significant levels.

The relationship between mean temperature and mean plant height and also that of mean temperature and mean stem diameter is an inverse relationship, while the relationship between mean plant height and mean relative humidity and mean dew and that of also between mean stem diameter and mean relative humidity and mean dew is a direct relationship, meaning an increase in one variable leads to an increase in the other and is significant at both 0.05 and 0.01 significant levels (see Appendix VIII).

There is no significant relationship between mean temperature ('r' value = - *0.797)* and mean dew ('r' value = *0.8*) and the mean leaf area at both 0.05 and 0.01 significant levels. On the other hand, there is a significant relationship between mean relative humidity and mean leaf area ('r' value = *0.861***)* in the sun treatment at 0.05 significant levels.

The mean plant height and the mean stem diameter and the leaf count also have a significant relationship with microclimatic conditions but the relationship is more significant between mean leaf count and mean relative humidity ('r' value = *0.951*** *)* and mean dew ('r' value *=0.931****)* than between mean temperature and mean leaf count ('r' value = - *0.831***)* because the relationship between mean leaf count and mean temperature is significant at only 0.05 significant levels while it is significant at both 0.05 and 0.01 significant levels between mean leaf count and mean relative humidity and mean dew.

There is also a significant relationship between mean fresh weight and microclimatic conditions. The relationship is however, more significant between mean relative humidity and mean fresh weight ('r' value = *0.992****)* than between mean temperature ('r' value = - *0.896***)* and mean dew and mean fresh weight ('r' value = *0.904***)* because the relationship between mean fresh weight and mean temperature and mean dew is significant at only 0.05 significant level while the relationship between mean relative humidity and mean fresh weight is significant at both 0.05 and 0.01 significant level (see Appendix VIII).

There is also a significant relationship between mean dry weight and microclimatic conditions. The relationship is however, more significant between mean relative humidity and mean dry weight ('r' value = *0.986***) than between mean temperature ('r' value = - *0.887**) and mean dew and mean dry weight ('r' value = *0.896**). This is because the relationship between mean temperature and mean dew and mean dry weight is significant at only 0.05 significant levels but the relationship between mean relative humidity and mean dry weight is significant at both 0.05 and 0.01 significant levels.

There is a significant relationship between crop growth rate and microclimatic conditions but the relationship is more significant between mean relative humidity and crop growth rate ('r' value = *0.921****)* than between mean temperature ('r' value = - *0.805***)* and mean dew and crop growth rate ('r' value = *0.897***)* because the relationship between mean relative humidity and crop growth rate is significant at both 0.05 and 0.01 significant levels while the relationship between mean temperature and mean dew and crop growth rate is only significant at 0.05 significant level (see Appendix VIII).

These findings revealed that there is a significant relationship between microclimatic conditions and early growth characteristics of *Jatropha curcas* seedlings in the sun treatment and there is no significant relationship between microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the shade treatment except between dew and number of days to seedlings emergence.

4.4 Difference in the Microclimatic Conditions and the Early Growth Characteristics of *Jatropha curcas* Seedlings

Student's paired t-test was used to test for the difference in the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings. The result is presented in section 4.4.1 and 4.4.2.

4.4.1 Difference in the Microclimatic Conditions between Shade and Sun Treatment

This sub-section presents and discusses the result of the difference in the microclimatic conditions between shade and sun treatments. It also tests the Second stated hypothesis that there is no significant difference in the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings between the shade and sun treatments.

4.4.1.1 Temperature

The result of the difference in the mean temperature between shade and sun treatments is presented in table 4.5.

Table 4.5 Difference in Mean Temperature between Shade and Sun Treatments

	Shade	*Sun*
Mean	30.33633	33.3904
Variance	3.384389	4.00821
Observations	6	6
Pearson Correlation	0.031296	
Hypothesized Mean Difference	0	
Df	5	
t Stat	2.79531	
P(T<=t) one-tail	**0.019102**	
t Critical one-tail	2.015048	
P(T<=t) two-tail	0.038205	
t Critical two-tail	2.570582	

Table 4.5 revealed that there is significant difference in the mean temperature between the shade and the sun treatments at 95% significant level because the *p* value 0.019102 is less than 0.05. This result did not contradict the general assumption that open spaced areas receives higher solar radiation compared to their shade counterparts and are therefore expected to have higher temperatures which might be significantly different from the shade. This implies that any difference in growth characteristics between the shade and sun treatments can be linked to temperature.

4.4.1.2 Relative humidity

Table 4.6 shows that there is no significant difference in the mean relative humidity between the shade and the sun treatments at both 95% and 99% significant levels because the *p* value 0.21415 is greater than 0.05. Hence any significant change in growth characteristics between the sun and the shade cannot be attributed to relative humidity.

Table 4.6 Difference in Mean Relative Humidity between Shade and Sun Treatments

	Shade	*Sun*
Mean	56.9479	51.754
Variance	97.1104	74.992
Observations	6	6
Pearson Correlation	-0.269	
Hypothesized Mean Difference	0	
Df	5	
t Stat	-0.8616	
P(T<=t) one-tail	**0.21415**	
t Critical one-tail	2.01505	
P(T<=t) two-tail	0.4283	
t Critical two-tail	2.57058	

4.4.1.3 Dew

The result of the difference in the mean dew between the shade and the sun treatments using paired t-Test is presented in table 4.7.

Table 4.7 Difference in Mean Dew between Shade and Sun Treatments

	Shade	*Sun*
Mean	20.0648	20.1819
Variance	1.6869	1.72035
Observations	6	6
Pearson Correlation	-0.5212	
Hypothesized Mean Difference	0	
Df	5	
t Stat	0.12601	
P(T<=t) one-tail	**0.45232**	

t Critical one-tail	2.01505
P(T<=t) two-tail	0.90464
t Critical two-tail	2.57058

From Table 4.7, it can be observed that there is no significant difference in the mean dew between the shade and the sun treatments at both 95% and 99% significant levels. This is because the *p* value 0.45232 is greater than 0.05. By implication therefore it can be deduced that a significant change in growth characteristic between the two treatments cannot be associated to dew conditions.

4.4.2 Difference in the Early Growth Characteristics of *Jatropha curcas* Seedlings between Shade and Sun Treatments

This sub-section presents and discusses the result of the difference in the early growth characteristics of *Jatropha curcas* seedlings between shade and sun treatments. It also tests the Second stated hypothesis that there is no significant difference in the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings between the shade and sun treatments.

4.4.2.1 Number of days to seedlings emergence

The result of the difference in the number of seedlings emergence between shade and sun treatments is presented in Table 4.8. From the table it can be observed that there is no significant difference in the number of seedlings that emerges between the shade and the sun treatments at both 95% and 99% significant levels because the *p* value 0.37033 is greater than 0.05. Therefore, the seedlings emergence can be associated with relative humidity and dew conditions in the shade and sun treatments.

Table 4.8 Difference in Mean Seedlings Emergence between Shade and Sun Treatments

	Shade	*Sun*
Mean	8.2	8.8
Variance	99.7	174.7
Observations	5	5
Pearson Correlation	0.98541	
Hypothesized Mean Difference	0	
Df	4	

t Stat	-0.3548
P(T<=t) one-tail	**0.37033**
t Critical one-tail	2.13185
P(T<=t) two-tail	0.74066
t Critical two-tail	2.77645

4.4.2.2 Plant height

The difference in mean plant height between the seedlings in the shade and those in the sun treatment is presented in Table 4.9.

Table 4.9 Difference in Mean Plant Height between Shade and Sun Treatments

	Shade	*Sun*
Mean	23.2833	36.7667
Variance	78.1137	463.943
Observations	6	6
Pearson Correlation	0.99017	
Hypothesized Mean Difference	0	
Df	5	
t Stat	-2.5707	
P(T<=t) one-tail	**0.025**	
t Critical one-tail	2.01505	
P(T<=t) two-tail	0.04999	
t Critical two-tail	2.57058	

From Table 4.9, it can be observed that there is a significant difference in mean plant height between the seedlings in the shade and those in the sun at 95% significant levels because the *p* value 0.025 is less than 0.05. This result shows that the difference in mean plant height between the two treatments is associated with differences in temperature between the two treatments.

4.4.2.3 Stem diameter

Table 4.10 shows that there is a significant difference in mean stem diameter between the seedlings in the shade and those in the sun at 95% significant level because the *p* value 0.0211 is less than 0.05.

Table 4.10 Difference in Mean Stem Diameter between Shade and Sun Treatments

	Shade	*Sun*
Mean	0.7	1.03333
Variance	0.052	0.26667
Observations	6	6
Pearson Correlation	0.9681	
Hypothesized Mean Difference	0	
df	5	
t Stat	-2.7116	
P(T<=t) one-tail	**0.0211**	
t Critical one-tail	2.01505	
P(T<=t) two-tail	0.04219	
t Critical two-tail	2.57058	

From this result it can be deduced that the change in mean stem diameter between the two treatments cannot be associated with relative humidity and dew conditions.

4.4.2.4 Leaf area

This sub-section presents the result of the difference in mean leaf area between the seedlings in the shade and those in the sun by t-Test: Paired Two Sample for Means. The result of the difference is given in Table 4.11.

Table 4.11 Difference in Mean Leaf Area between the Shade and the Sun Treatments

	Shade	*Sun*
Mean	37.8	42.5667
Variance	29.428	176.911
Observations	6	6
Pearson Correlation	0.96475	
Hypothesized Mean Difference	0	
Df	5	
t Stat	-1.4252	
P(T<=t) one-tail	**0.10671**	
t Critical one-tail	2.01505	
P(T<=t) two-tail	0.21342	
t Critical two-tail	2.57058	

From Table 4.11, it can be observed that there is no significant difference at both 95% and 99% significant level in mean leaf area between the seedlings in the shade and those in the sun because the *p* value 0.10671 is greater than 0.05. The result indicates that the mean leaf area might not be affected by temperature, since significant change in temperature between the two treatments does not make significant difference in mean leaf area.

4.4.2.5 Leaf count

Table 4.12, shows that there is a significant difference in mean leaf count at 95% level of significant between the seedlings in the shade and those in the sun treatment. This is because the *p* value 0.0299 is less than 0.05. The result cannot be attributed to relative humidity and dew conditions since they give no significant difference between shade and sun treatments; hence it can be linked to temperature.

Table 4.12 Difference in Mean Leaf Count between the Shade and the Sun Treatments

	Shade	*Sun*
Mean	9.83333	15
Variance	30.1667	113.92
Observations	6	6
Pearson Correlation	0.99648	
Hypothesized Mean Difference	0	
Df	5	
t Stat	-2.4242	
P(T<=t) one-tail	**0.0299**	
t Critical one-tail	2.01505	
P(T<=t) two-tail	0.05981	
t Critical two-tail	2.57058	

4.4.2.6 Fresh weight

The result of the difference in mean fresh weight between the seedlings in the shade and those in the sun is shown in table 4.13.

Table 4.13 Difference in Mean Fresh Weight between Shade and Sun Treatments

	Shade	*Sun*
Mean	24.95	85.7
Variance	568.027	9602.46
Observations	6	6
Pearson Correlation	0.98735	

Hypothesized Mean Difference	0
Df	5
t Stat	-1.9959
P(T<=t) one-tail	**0.05124**
t Critical one-tail	2.01505
P(T<=t) two-tail	0.10248
t Critical two-tail	2.57058

From table 4.13, it can be deduced that there is no significant difference in mean fresh weight between the seedlings in the shade and those in the sun at both 95% and 99% levels of significant. This is because the *p* value 0.05124 is slightly greater than 0.05. It implies that the mean fresh weight can be associated with mean relative humidity and dew conditions in both treatments.

4.4.2.7 Dry weight

This sub- section gives the result of the difference in mean dry weight between the seedlings in the shade and those in the sun treatment obtained by t-Test: Paired Two Sample for Means. The result is presented in Table 4.14.

Table 4.14 Difference in Mean Dry Weight between Shade and Sun Treatments

	Shade	*Sun*
Mean	4.4	17.4167
Variance	26.036	491.762
Observations	6	6
Pearson Correlation	0.99183	
Hypothesized Mean Difference	0	
Df	5	
t Stat	-1.8616	
P(T<=t) one-tail	**0.06086**	
t Critical one-tail	2.01505	
P(T<=t) two-tail	0.12172	
t Critical two-tail	2.57058	

Table 4.14 shows that there is no significant difference in mean dry weight between the seedlings in the shade and those in the sun at both 99% and 95% levels of significant because the *p* value 0.06086 is greater than 0.05. This result can be explained in the same way as fresh weight.

4.4.2.8 Crop growth rate

The difference in calculated crop growth rate between the two treatments obtained by t-Test: Paired Two Sample for Means is presented in table 4.15.

Table 4.15 Difference in Crop Growth Rate between Shade and Sun Treatments

	Shade	*Sun*
Mean	1.167	4.667
Variance	1.847	27.535
Observations	6	6
Pearson Correlation	0.920	
Hypothesized Mean Difference	0	
Df	5	
t Stat	-2.126	
P(T<=t) one-tail	**0.043**	
t Critical one-tail	2.015	
P(T<=t) two-tail	0.087	
t Critical two-tail	2.571	

From Table 4.15, it can be observed that there is a significant difference in crop growth rate between the seedlings in the shade and those in the sun at 95% significant level because the *p* value 0.043 is less than 0.05. The result emphasized the significant role played by temperature in accelerating chemical reactions within plants which result in rapid growth. However, the result did not show any evidence of the influence of relative humidity and dew conditions in crop growth rate because there is no significant difference in relative humidity and dew conditions between the shade and sun treatments.

4.5 Hypotheses Testing

This section tested the two hypotheses stated at the beginning of the study (chapter one).

4.5.1 Test of the Relationship between the Microclimatic Conditions and the Early Growth Characteristics of *Jatropha curcas* Seedlings in the two Experimental Treatments

The first hypothesis stated that there is no significant relationship between the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the shade and sun treatments. To test this hypothesis, Pearsons' product moment correlation was employed.

This hypothesis was previously presented and discussed under tables 4.1, 4.2, 4.3 and 4.4. The results revealed that there is no significant relationship between the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the shade treatment at both 0.01 and 0.05 significant levels except between mean dew and number of days to seedlings emergence ('r' value = - 0.888*) at 0.05 significant level. Thus, the null hypothesis of study can be retained in this case.

However, the result of the relationship between microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the sun treatment revealed that there is a significant relationship between the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the sun treatments at both 0.01 and 0.05 significant levels. Thus, the study rejected the stated null hypothesis.

4.5.2 Test of the Difference in the Microclimatic Conditions and the Early Growth Characteristics of *Jatropha curcas* Seedlings between the two Experimental Treatments

The second hypothesis states that there is no significant difference in the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings between the shade and sun treatments. To test this hypothesis, Students' paired t-test was employed.

This hypothesis was previously presented and discussed under tables 4.5 to 4.15. The results revealed that there are significant differences in mean temperature, mean plant height, mean stem diameter, mean leaf count and crop growth rate between the shade and the sun treatments. Therefore, the null hypothesis is in this case nullified.

However, the result also revealed that there is no significant difference in mean relative humidity, mean dew, seedlings emergence, leaf area, fresh weight and dry weight between the shade and sun treatments. In this case, the null hypothesis is accepted.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of the study, conclusion and recommendations based on the findings of the study.

5.2 Summary

This study examines the effects of microclimatic conditions (temperature, relative humidity and Dew) on the early growth of *Jatropha curcas* seedlings (seedlings emergence, plant height, stem diameter, leaf area, leaf count, fresh weight, dry weight and crop growth rate) in Kano, Nigeria. It is an experimental study conducted at Forestry Research Institute of Nigeria, Shelterbelt Research Station Nursery, Kano with two treatments (shade and sun) laid in a Completely Randomized Design (CRD) with six repetitions at 2,4, 6, 8, 10 and 12 Weeks After Sowing (WAS) the seeds. The microclimatic conditions were recorded with the aid of two lascar EL-USB Temperature/Relative Humidity data loggers, one for each of the treatments; the experiment covers a period of twelve (12) weeks (3 months) from 20 April, 2014 to 14 July, 2014. Data generated from the Data loggers and Nursery works were subjected to analysis using Statistical Package for Social Science (SPSS). Line and bar graphs were used to describe the results. Pearson's product moment correlation was used to test for the relationship between microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings at both the shade and sun treatments.

Similarly, paired student t- test was also used to test for the difference in microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings between the two treatments (shade and sun). The findings of the study revealed the following.

i. The mean temperature values recorded in the sun were higher than those in the shade throughout the period of the study except at 12 WAS when the mean temperature in the shade rose slightly higher than the sun mean temperature.

ii. The mean relative humidity values recorded in the sun were lower than those in the shade except at 10 and 12 WAS when the mean relative humidity in the sun slightly rose above those in the shade. This might be because an increase in temperature is associated with a decrease in relative humidity.

iii. The mean dew recorded in the sun was higher compared to those in the shade except at 2 and 4 WAS when the mean dew recorded in shade slightly rose above those in sun. This implies that most of the microclimatic conditions recorded in the sun were higher compared to their shade counterparts.

iv. The mean early growth characteristics of *Jatropha curcas* seedlings' values recorded in the sun were higher than those recorded in the shade. This indicates that nurturing seedlings in the sun gives better growth results. This might be as a result of the role played by sun light and temperature during the process of photosynthesis.

v. There is no significant relationship between the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the shade treatment at both 0.01 and 0.05 significant levels except between mean dew and number of days to seedlings' emergence ('r' value = - 0.888^{*}) at 0.05 significant level.

vi. There is a significant relationship between the microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings in the sun treatment at both 0.01 and 0.05 significant levels.

vii. There is a significant difference in mean temperature, mean plant height, mean stem diameter, mean leaf count and crop growth rate between shade and sun treatments at 95% level of significance.

viii. There is no significant difference in mean relative humidity, mean dew, number of days to seedlings emergence, mean leaf area, mean fresh weight and mean dry weight between the shade and sun treatments at both 99% and 95% levels of significant.

5.3 Conclusion

This study made the following conclusions:

i. That microclimatic condition affect seedlings' early growth characteristics by increasing the rate of growth, plant height, stem diameter, and leaf count.

ii. That *Jatropha curcas* seedlings nurtured in the sun grows faster than their shade counterparts due to the vital role played by sunlight during photosynthesis and other growth processes.

iii. That there is a significant relationship between microclimatic conditions and the early growth characteristics of *Jatropha curcas* seedlings nurtured in the sun.

iv. That there is no significant difference between shade and sun treatments in relative humidity and dew condition. The difference is significant only in temperature; hence any change in the growth characteristics can be attributed to temperature variation.

v. That the problems of nurturing seedlings can be tackled effectively by integrating the knowledge of microclimatic conditions suitable for raising the seedlings with technical expertise.

5.4 Recommendations

On the basis of the findings, the study made the following recommendations.

i. Farmers and Entrepreneurs should be encouraged to raise *Jatropha curcas* seedlings in an open space to avoid shading effect. This will allow the seedlings to absorb more sunlight for photosynthesis.

ii. Farmers or Entrepreneurs should be enlightened on the microclimates of their areas and how it affects seedlings production. This will allow them to understand when, how and where to raise seedlings.

iii. Researches like this could be useful to farmers and entrepreneurs in producing large scale *Jatropha curcas* seedlings for bio diesel, chemical synthesis and other uses.

iv. More researches are still required in this area, such as examining the effects of sun light or other microclimatic elements on the early growth of *Jatropha curcas* seedlings in the study area or in other regions of the country.

v. Effects of microclimatic conditions on the phenological stages (flowering, fruiting and yield) of *Jatropha curcas* plant could be a good area for future studies.

vi. Integrated study of the soil and climatic conditions suitable for the propagation of *Jatropha curcas* plant in Nigeria could be another area for future researches.

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APPENDICES

Appendix I: Shade Microclimatic Conditions' Data

S/N	WAS	Date	Time	Temp(^{o}C)	Humidity(%rh)	Dew
1	wk2	4/20/2014	12:00:00	36	40	20.3
2	wk2	4/20/2014	18:00:00	38.5	36	20.8
3	wk2	4/21/2014	0:00:00	29	54	18.7
4	wk2	4/21/2014	6:00:00	27	61.5	19
5	wk2	4/21/2014	12:00:00	33	49	20.9
6	wk2	4/21/2014	18:00:00	38	23.5	13.6
7	wk2	4/22/2014	0:00:00	33	35.5	15.7
8	wk2	4/22/2014	6:00:00	29	55.5	19.2
9	wk2	4/22/2014	12:00:00	34	46	20.7
10	wk2	4/22/2014	18:00:00	38.5	27	16.2
11	wk2	4/23/2014	0:00:00	33	23	9.1
12	wk2	4/23/2014	6:00:00	28.5	62.5	20.6
13	wk2	4/23/2014	12:00:00	33.5	50.5	21.8
14	wk2	4/23/2014	18:00:00	38.5	24.5	14.7
15	wk2	4/24/2014	0:00:00	33	34	15
16	wk2	4/24/2014	6:00:00	30	53	19.4
17	wk2	4/24/2014	12:00:00	35	39.5	19.2
18	wk2	4/24/2014	18:00:00	38.5	27	16.2
19	wk2	4/25/2014	0:00:00	31.5	45	18.1
20	wk2	4/25/2014	6:00:00	28	55	18.1
21	wk2	4/25/2014	12:00:00	34	46.5	20.9
22	wk2	4/25/2014	18:00:00	38.5	30.5	18.1
23	wk2	4/26/2014	0:00:00	33.5	41.5	18.6
24	wk2	4/26/2014	6:00:00	29.5	52.5	18.8
25	wk2	4/26/2014	12:00:00	34	50.5	22.3
26	wk2	4/26/2014	18:00:00	38	38	21.2
27	wk2	4/27/2014	0:00:00	22.5	87.5	20.3
28	wk2	4/27/2014	6:00:00	24	73	18.9
29	wk2	4/27/2014	12:00:00	30	57.5	20.7
30	wk2	4/27/2014	18:00:00	35.5	39	19.4
31	wk2	4/28/2014	0:00:00	30.5	51	19.2
32	wk2	4/28/2014	6:00:00	26	65.5	19
33	wk2	4/28/2014	12:00:00	32	47.5	19.4
34	wk2	4/28/2014	18:00:00	37.5	36	19.9
35	wk2	4/29/2014	0:00:00	29.5	48	17.3
36	wk2	4/29/2014	6:00:00	27	62	19.1
37	wk2	4/29/2014	12:00:00	31	54	20.6

38	wk2	4/29/2014	18:00:00	37	33	18.1
39	wk2	4/30/2014	0:00:00	33	43.5	18.9
40	wk2	4/30/2014	6:00:00	29.5	59	20.6
41	wk2	4/30/2014	12:00:00	34.5	42.5	19.9
42	wk2	4/30/2014	18:00:00	39	30.5	18.5
43	wk2	5/1/2014	0:00:00	28.5	59.5	19.8
44	wk2	5/1/2014	6:00:00	26.5	65	19.4
45	wk2	5/1/2014	12:00:00	33	46	19.8
46	wk2	5/1/2014	18:00:00	38	29.5	17.1
47	wk2	5/2/2014	0:00:00	33	43	18.7
48	wk2	5/2/2014	6:00:00	29.5	60	20.9
49	wk2	5/2/2014	12:00:00	33.5	48.5	21.1
50	wk2	5/2/2014	18:00:00	38	33	18.9
51	wk2	5/3/2014	0:00:00	26.5	79.5	22.7
52	wk2	5/3/2014	6:00:00	26.5	74	21.5
53	wk2	5/3/2014	12:00:00	30.5	63	22.7
54	wk2	5/3/2014	18:00:00	30.5	57.5	21.2
55	wk2	5/4/2014	0:00:00	26	68.5	19.8
56	wk2	5/4/2014	6:00:00	24.5	78	20.4
57	wk2	5/4/2014	12:00:00	28	65.5	20.9
58	wk2	5/4/2014	18:00:00	34.5	42.5	19.9
59	wk2	5/5/2014	0:00:00	30	55	20
60	wk2	5/5/2014	6:00:00	28	65.5	20.9
61	wk2	5/5/2014	12:00:00	33	51.5	21.7
62	wk2	5/5/2014	18:00:00	35	41.5	20
63	wk4	5/6/2014	0:00:00	28.5	62.5	20.6
64	wk4	5/6/2014	6:00:00	22.5	98	22.2
65	wk4	5/6/2014	12:00:00	26.5	79	22.6
66	wk4	5/6/2014	18:00:00	32.5	53.5	21.8
67	wk4	5/7/2014	0:00:00	28.5	65.5	21.4
68	wk4	5/7/2014	6:00:00	25.5	79.5	21.7
69	wk4	5/7/2014	12:00:00	25	88	22.9
70	wk4	5/7/2014	18:00:00	31	60	22.3
71	wk4	5/8/2014	0:00:00	27.5	75	22.7
72	wk4	5/8/2014	6:00:00	25	83.5	22
73	wk4	5/8/2014	12:00:00	30.5	61	22.1
74	wk4	5/8/2014	18:00:00	33	54.5	22.6
75	wk4	5/9/2014	0:00:00	28.5	66.5	21.6
76	wk4	5/9/2014	6:00:00	26	78.5	22
77	wk4	5/9/2014	12:00:00	30.5	64	22.9
78	wk4	5/9/2014	18:00:00	35.5	40.5	20
79	wk4	5/10/2014	0:00:00	30.5	52	19.5
80	wk4	5/10/2014	6:00:00	28	58	19

81	wk4	5/10/2014	12:00:00	28.5	55	18.6
82	wk4	5/10/2014	18:00:00	31.5	48.5	19.3
83	wk4	5/11/2014	0:00:00	27	62.5	19.2
84	wk4	5/11/2014	6:00:00	26	66.5	19.3
85	wk4	5/11/2014	12:00:00	31.5	45.5	18.3
86	wk4	5/11/2014	18:00:00	36	25.5	13.2
87	wk4	5/12/2014	0:00:00	30.5	41.5	15.9
88	wk4	5/12/2014	6:00:00	27.5	53	17.1
89	wk4	5/12/2014	12:00:00	33	45	19.5
90	wk4	5/12/2014	18:00:00	37	26	14.3
91	wk4	5/13/2014	0:00:00	32	37	15.5
92	wk4	5/13/2014	6:00:00	29	53	18.4
93	wk4	5/13/2014	12:00:00	32.5	46.5	19.6
94	wk4	5/13/2014	18:00:00	29	54.5	18.9
95	wk4	5/14/2014	0:00:00	27	62.5	19.2
96	wk4	5/14/2014	6:00:00	25.5	64	18.2
97	wk4	5/14/2014	12:00:00	30	50.5	18.6
98	wk4	5/14/2014	18:00:00	33.5	32	14.5
99	wk4	5/15/2014	0:00:00	30	48	17.8
100	wk4	5/15/2014	6:00:00	28	41	13.5
101	wk4	5/15/2014	12:00:00	31.5	29	11.3
102	wk4	5/15/2014	18:00:00	36.5	19	9.2
103	wk4	5/16/2014	0:00:00	31	33.5	13.1
104	wk4	5/16/2014	6:00:00	27.5	39	12.3
105	wk4	5/16/2014	12:00:00	33.5	41.5	18.6
106	wk4	5/16/2014	18:00:00	37.5	22.5	12.5
107	wk4	5/17/2014	0:00:00	31.5	31.5	12.6
108	wk4	5/17/2014	6:00:00	28.5	45	15.4
109	wk4	5/17/2014	12:00:00	32.5	47	19.7
110	wk4	5/17/2014	18:00:00	37.5	25.5	14.4
111	wk4	5/18/2014	0:00:00	32	36.5	15.3
112	wk4	5/18/2014	6:00:00	29	50.5	17.7
113	wk4	5/18/2014	12:00:00	34.5	47	21.5
114	wk4	5/18/2014	18:00:00	38.5	28	16.7
115	wk4	5/19/2014	0:00:00	32.5	42.5	18.1
116	wk4	5/19/2014	6:00:00	27.5	60	19
117	wk4	5/19/2014	12:00:00	32.5	45.5	19.2
118	wk4	5/19/2014	18:00:00	36	38	19.4
119	wk6	5/20/2014	0:00:00	32	50.5	20.4
120	wk6	5/20/2014	6:00:00	29	51	17.8
121	wk6	5/20/2014	12:00:00	32.5	43	18.3
122	wk6	5/20/2014	18:00:00	36	34	17.7
123	wk6	5/21/2014	0:00:00	32.5	45.5	19.2

124	wk6	5/21/2014	6:00:00	29	64.5	21.6
125	wk6	5/21/2014	12:00:00	34	51.5	22.6
126	wk6	5/21/2014	18:00:00	39.5	22	13.8
127	wk6	5/22/2014	0:00:00	32.5	31.5	13.4
128	wk6	5/22/2014	6:00:00	29	61.5	20.8
129	wk6	5/22/2014	12:00:00	33	52.5	22
130	wk6	5/22/2014	18:00:00	38.5	27	16.2
131	wk6	5/23/2014	0:00:00	31	43	17
132	wk6	5/23/2014	6:00:00	28	49	16.3
133	wk6	5/23/2014	12:00:00	34	42.5	19.5
134	wk6	5/23/2014	18:00:00	39	21.5	13.1
135	wk6	5/24/2014	0:00:00	32.5	44	18.7
136	wk6	5/24/2014	6:00:00	29	55.5	19.2
137	wk6	5/24/2014	12:00:00	33.5	49.5	21.5
138	wk6	5/24/2014	18:00:00	39	32	19.3
139	wk6	5/25/2014	0:00:00	33	44	19.1
140	wk6	5/25/2014	6:00:00	30	55.5	20.1
141	wk6	5/25/2014	12:00:00	33	49.5	21
142	wk6	5/25/2014	18:00:00	37.5	38	20.8
143	wk6	5/26/2014	0:00:00	31.5	44.5	17.9
144	wk6	5/26/2014	6:00:00	27	66.5	20.2
145	wk6	5/26/2014	12:00:00	33	51	21.5
146	wk6	5/26/2014	18:00:00	40	27	17.4
147	wk6	5/27/2014	0:00:00	32.5	44.5	18.8
148	wk6	5/27/2014	6:00:00	28	61.5	19.9
149	wk6	5/27/2014	12:00:00	33	48	20.5
150	wk6	5/27/2014	18:00:00	38	33.5	19.2
151	wk6	5/28/2014	0:00:00	25	86	22.5
152	wk6	5/28/2014	6:00:00	25	76	20.5
153	wk6	5/28/2014	12:00:00	29.5	66	22.5
154	wk6	5/28/2014	18:00:00	33	47	20.2
155	wk6	5/29/2014	0:00:00	28	60	19.5
156	wk6	5/29/2014	6:00:00	25.5	73	20.3
157	wk6	5/29/2014	12:00:00	30	62	21.9
158	wk6	5/29/2014	18:00:00	34	48.5	21.6
159	wk6	5/30/2014	0:00:00	27.5	59.5	18.9
160	wk6	5/30/2014	6:00:00	25	70.5	19.3
161	wk6	5/30/2014	12:00:00	30	57	20.5
162	wk6	5/30/2014	18:00:00	36	38	19.4
163	wk6	5/31/2014	0:00:00	31	55.5	21
164	wk6	5/31/2014	6:00:00	27.5	70	21.5
165	wk6	5/31/2014	12:00:00	32.5	55	22.3
166	wk6	5/31/2014	18:00:00	37.5	40	21.6

167	wk6	6/1/2014	0:00:00	32.5	54	22
168	wk6	6/1/2014	6:00:00	26	61	17.9
169	wk6	6/1/2014	12:00:00	28.5	57.5	19.3
170	wk6	6/1/2014	18:00:00	36.5	37.5	19.7
171	wk6	6/2/2014	0:00:00	31.5	52.5	20.6
172	wk6	6/2/2014	6:00:00	27.5	62	19.6
173	wk6	6/2/2014	12:00:00	32	49	19.9
174	wk6	6/2/2014	18:00:00	37.5	36.5	20.1
175	wk8	6/3/2014	0:00:00	32	53	21.2
176	wk8	6/3/2014	6:00:00	22.5	81	19.1
177	wk8	6/3/2014	12:00:00	28.5	65.5	21.4
178	wk8	6/3/2014	18:00:00	34.5	44.5	20.6
179	wk8	6/4/2014	0:00:00	31	59	22
180	wk8	6/4/2014	6:00:00	28	66	21.1
181	wk8	6/4/2014	12:00:00	31.5	57.5	22.1
182	wk8	6/4/2014	18:00:00	37	36.5	19.7
183	wk8	6/5/2014	0:00:00	33	49.5	21
184	wk8	6/5/2014	6:00:00	29	66	22
185	wk8	6/5/2014	12:00:00	32.5	56	22.6
186	wk8	6/5/2014	18:00:00	35	40	19.4
187	wk8	6/6/2014	0:00:00	32	49	19.9
188	wk8	6/6/2014	6:00:00	26	55.5	16.4
189	wk8	6/6/2014	12:00:00	29	55.5	19.2
190	wk8	6/6/2014	18:00:00	34.5	40.5	19.1
191	wk8	6/7/2014	0:00:00	30	48	17.8
192	wk8	6/7/2014	6:00:00	28	65.5	20.9
193	wk8	6/7/2014	12:00:00	31.5	54	21.1
194	wk8	6/7/2014	18:00:00	34.5	44.5	20.6
195	wk8	6/8/2014	0:00:00	30.5	60.5	22
196	wk8	6/8/2014	6:00:00	28	67.5	21.4
197	wk8	6/8/2014	12:00:00	32.5	57	22.9
198	wk8	6/8/2014	18:00:00	37	39.5	20.9
199	wk8	6/9/2014	0:00:00	30.5	48.5	18.4
200	wk8	6/9/2014	6:00:00	27.5	55	17.7
201	wk8	6/9/2014	12:00:00	31.5	53.5	20.9
202	wk8	6/9/2014	18:00:00	36.5	40	20.7
203	wk8	6/10/2014	0:00:00	29	55.5	19.2
204	wk8	6/10/2014	6:00:00	22.5	90.5	20.9
205	wk8	6/10/2014	12:00:00	26	73.5	20.9
206	wk8	6/10/2014	18:00:00	32.5	46.5	19.6
207	wk8	6/11/2014	0:00:00	28.5	56.5	19
208	wk8	6/11/2014	6:00:00	25.5	69	19.4
209	wk8	6/11/2014	12:00:00	32	50	20.3

210	wk8	6/11/2014	18:00:00	36	38	19.4
211	wk8	6/12/2014	0:00:00	32	48	19.6
212	wk8	6/12/2014	6:00:00	28.5	64	21
213	wk8	6/12/2014	12:00:00	32	57	22.4
214	wk8	6/12/2014	18:00:00	36	42	21.1
215	wk8	6/13/2014	0:00:00	30.5	50	18.9
216	wk8	6/13/2014	6:00:00	27.5	61.5	19.4
217	wk8	6/13/2014	12:00:00	32	54.5	21.7
218	wk8	6/13/2014	18:00:00	37.5	37.5	20.5
219	wk8	6/14/2014	0:00:00	32	46	18.9
220	wk8	6/14/2014	6:00:00	27.5	56.5	18.1
221	wk8	6/14/2014	12:00:00	30.5	51	19.2
222	wk8	6/14/2014	18:00:00	37	37	19.9
223	wk8	6/15/2014	0:00:00	28.5	52	17.7
224	wk8	6/15/2014	6:00:00	26	64	18.7
225	wk8	6/15/2014	12:00:00	31.5	50	19.8
226	wk8	6/15/2014	18:00:00	36	39.5	20.1
227	wk8	6/16/2014	0:00:00	30.5	59.5	21.7
228	wk8	6/16/2014	6:00:00	27.5	70.5	21.7
229	wk8	6/16/2014	12:00:00	32	58	22.7
230	wk8	6/16/2014	18:00:00	25.5	84.5	22.7
231	wk10	6/17/2014	0:00:00	24	84	21.1
232	wk10	6/17/2014	6:00:00	24	85.5	21.4
233	wk10	6/17/2014	12:00:00	29	68.5	22.6
234	wk10	6/17/2014	18:00:00	33.5	50.5	21.8
235	wk10	6/18/2014	0:00:00	23.5	95.5	22.7
236	wk10	6/18/2014	6:00:00	23.5	87	21.2
237	wk10	6/18/2014	12:00:00	29.5	69	23.2
238	wk10	6/18/2014	18:00:00	32.5	61	24
239	wk10	6/19/2014	0:00:00	28.5	73.5	23.3
240	wk10	6/19/2014	6:00:00	25	74	20
241	wk10	6/19/2014	12:00:00	30.5	52	19.5
242	wk10	6/19/2014	18:00:00	35	41.5	20
243	wk10	6/20/2014	0:00:00	30	61.5	21.8
244	wk10	6/20/2014	6:00:00	27	75	22.2
245	wk10	6/20/2014	12:00:00	30.5	61	22.1
246	wk10	6/20/2014	18:00:00	35	47.5	22.2
247	wk10	6/21/2014	0:00:00	31	60	22.3
248	wk10	6/21/2014	6:00:00	27.5	68.5	21.2
249	wk10	6/21/2014	12:00:00	31.5	60	22.8
250	wk10	6/21/2014	18:00:00	36	44	21.8
251	wk10	6/22/2014	0:00:00	31.5	58	22.2
252	wk10	6/22/2014	6:00:00	28.5	69	22.3

253	wk10	6/22/2014	12:00:00	31.5	54.5	21.2
254	wk10	6/22/2014	18:00:00	35.5	46.5	22.3
255	wk10	6/23/2014	0:00:00	30	54	19.7
256	wk10	6/23/2014	6:00:00	25.5	56.5	16.2
257	wk10	6/23/2014	12:00:00	31.5	58	22.2
258	wk10	6/23/2014	18:00:00	33.5	48	21
259	wk10	6/24/2014	0:00:00	29	58	19.9
260	wk10	6/24/2014	6:00:00	25.5	68	19.2
261	wk10	6/24/2014	12:00:00	31	53	20.3
262	wk10	6/24/2014	18:00:00	36	38.5	19.6
263	wk10	6/25/2014	0:00:00	31	48	18.7
264	wk10	6/25/2014	6:00:00	27	61.5	19
265	wk10	6/25/2014	12:00:00	31.5	47	18.8
266	wk10	6/25/2014	18:00:00	36.5	37	19.4
267	wk10	6/26/2014	0:00:00	29	51	17.8
268	wk10	6/26/2014	6:00:00	26.5	55.5	16.9
269	wk10	6/26/2014	12:00:00	31.5	54.5	21.2
270	wk10	6/26/2014	18:00:00	35	45.5	21.5
271	wk10	6/27/2014	0:00:00	29.5	51	18.3
272	wk10	6/27/2014	6:00:00	26.5	62.5	18.8
273	wk10	6/27/2014	12:00:00	29.5	61.5	21.3
274	wk10	6/27/2014	18:00:00	35.5	43	21
275	wk10	6/28/2014	0:00:00	31	50	19.4
276	wk10	6/28/2014	6:00:00	25	71	19.4
277	wk10	6/28/2014	12:00:00	30	54.5	19.8
278	wk10	6/28/2014	18:00:00	24	88.5	22
279	wk10	6/29/2014	0:00:00	24.5	80	20.8
280	wk10	6/29/2014	6:00:00	22	98.5	21.8
281	wk10	6/29/2014	12:00:00	27	73	21.7
282	wk10	6/29/2014	18:00:00	32.5	54.5	22.1
283	wk10	6/30/2014	0:00:00	28.5	68	22
284	wk10	6/30/2014	6:00:00	26	82	22.7
285	wk10	6/30/2014	12:00:00	30	67	23.2
286	wk10	6/30/2014	18:00:00	34.5	53.5	23.7
287	wk12	7/1/2014	0:00:00	26	62.5	18.3
288	wk12	7/1/2014	6:00:00	23	88.5	21
289	wk12	7/1/2014	12:00:00	26	77	21.7
290	wk12	7/1/2014	18:00:00	34	45.5	20.6
291	wk12	7/2/2014	0:00:00	29.5	62	21.4
292	wk12	7/2/2014	6:00:00	26.5	76.5	22
293	wk12	7/2/2014	12:00:00	29	68.5	22.6
294	wk12	7/2/2014	18:00:00	33.5	50	21.6
295	wk12	7/3/2014	0:00:00	29	66	22

296	wk12	7/3/2014	6:00:00	27	79.5	23.1
297	wk12	7/3/2014	12:00:00	30	67	23.2
298	wk12	7/3/2014	18:00:00	25	92	23.6
299	wk12	7/4/2014	0:00:00	24	84	21.1
300	wk12	7/4/2014	6:00:00	23.5	87	21.2
301	wk12	7/4/2014	12:00:00	28	70	22
302	wk12	7/4/2014	18:00:00	33	51.5	21.7
303	wk12	7/5/2014	0:00:00	28.5	66.5	21.6
304	wk12	7/5/2014	6:00:00	25	76	20.5
305	wk12	7/5/2014	12:00:00	28.5	66.5	21.6
306	wk12	7/5/2014	18:00:00	32.5	55	22.3
307	wk12	7/6/2014	0:00:00	28.5	67.5	21.9
308	wk12	7/6/2014	6:00:00	26	73.5	20.9
309	wk12	7/6/2014	12:00:00	20	98	19.7
310	wk12	7/6/2014	18:00:00	25	83	21.9
311	wk12	7/7/2014	0:00:00	23.5	84.5	20.7
312	wk12	7/7/2014	6:00:00	22.5	90	20.8
313	wk12	7/7/2014	12:00:00	27	80	23.3
314	wk12	7/7/2014	18:00:00	30.5	61	22.1
315	wk12	7/8/2014	0:00:00	27	77.5	22.7
316	wk12	7/8/2014	6:00:00	25.5	83.5	22.5
317	wk12	7/8/2014	12:00:00	29	71.5	23.3
318	wk12	7/8/2014	18:00:00	24	78.5	20
319	wk12	7/9/2014	0:00:00	23	85	20.3
320	wk12	7/9/2014	6:00:00	22.5	90	20.8
321	wk12	7/9/2014	12:00:00	27	74	22
322	wk12	7/9/2014	18:00:00	30.5	65	23.2
323	wk12	7/10/2014	0:00:00	27	75.5	22.3
324	wk12	7/10/2014	6:00:00	24.5	86	22
325	wk12	7/10/2014	12:00:00	28.5	75	23.6
326	wk12	7/10/2014	18:00:00	32	64	24.3
327	wk12	7/11/2014	0:00:00	29	75	24.1
328	wk12	7/11/2014	6:00:00	26.5	85	23.8
329	wk12	7/11/2014	12:00:00	30	69	23.7
330	wk12	7/11/2014	18:00:00	33.5	54.5	23.1
331	wk12	7/12/2014	0:00:00	23	97	22.5
332	wk12	7/12/2014	6:00:00	23	88.5	21
333	wk12	7/12/2014	12:00:00	28	75.5	23.3
334	wk12	7/12/2014	18:00:00	24	83.5	21
335	wk12	7/13/2014	0:00:00	22.5	85.5	19.9
336	wk12	7/13/2014	6:00:00	21.5	91.5	20.1
337	wk12	7/13/2014	12:00:00	27	76.5	22.5
338	wk12	7/13/2014	18:00:00	31.5	61.5	23.2

339	wk12	7/14/2014	0:00:00	27.5	75	22.7
340	wk12	7/14/2014	6:00:00	25.5	81.5	22.1
341	wk12	7/14/2014	12:00:00	30.5	65	23.2

Appendix II: Sun Microclimatic Conditions' Data

S/N	WAS	Date	Time	Temp(^{o}C)	Humidity(%rh)	Dew
1	wk2	4/20/2014	12:00:00	40.5	35.5	22.3
2	wk2	4/20/2014	18:00:00	48.5	21	20.4
3	wk2	4/21/2014	0:00:00	28.5	56	18.9
4	wk2	4/21/2014	6:00:00	25.5	68.5	19.3
5	wk2	4/21/2014	12:00:00	38.5	38.5	21.9
6	wk2	4/21/2014	18:00:00	49.5	14.5	15.4
7	wk2	4/22/2014	0:00:00	32	36.5	15.3
8	wk2	4/22/2014	6:00:00	27.5	61	19.3
9	wk2	4/22/2014	12:00:00	39	37.5	21.9
10	wk2	4/22/2014	18:00:00	47.5	16.5	15.8
11	wk2	4/23/2014	0:00:00	31	22.5	7.1
12	wk2	4/23/2014	6:00:00	26.5	69.5	20.5
13	wk2	4/23/2014	12:00:00	37.5	41.5	22.2
14	wk2	4/23/2014	18:00:00	50.5	14	15.6
15	wk2	4/24/2014	0:00:00	31	34	13.3
16	wk2	4/24/2014	6:00:00	29	54	18.7
17	wk2	4/24/2014	12:00:00	39.5	31	19.2
18	wk2	4/24/2014	18:00:00	48.5	17	17.1
19	wk2	4/25/2014	0:00:00	31	45.5	17.8
20	wk2	4/25/2014	6:00:00	27	57.5	17.9
21	wk2	4/25/2014	12:00:00	38.5	37.5	21.4
22	wk2	4/25/2014	18:00:00	48.5	18.5	18.4
23	wk2	4/26/2014	0:00:00	32.5	42	17.9
24	wk2	4/26/2014	6:00:00	28.5	55.5	18.7
25	wk2	4/26/2014	12:00:00	36.5	44	22.3
26	wk2	4/26/2014	18:00:00	44.5	26.5	20.9
27	wk2	4/27/2014	0:00:00	22	91	20.5
28	wk2	4/27/2014	6:00:00	23.5	74.5	18.7
29	wk2	4/27/2014	12:00:00	34	47.5	21.3
30	wk2	4/27/2014	18:00:00	48.5	20	19.7
31	wk2	4/28/2014	0:00:00	29	54	18.7
32	wk2	4/28/2014	6:00:00	25	70	19.1
33	wk2	4/28/2014	12:00:00	36	39.5	20.1
34	wk2	4/28/2014	18:00:00	47	22.5	20.3
35	wk2	4/29/2014	0:00:00	28.5	49	16.7
36	wk2	4/29/2014	6:00:00	26	65	18.9

37	wk2	4/29/2014	12:00:00	37.5	40	21.6
38	wk2	4/29/2014	18:00:00	51	16.5	18.6
39	wk2	4/30/2014	0:00:00	32.5	44	18.7
40	wk2	4/30/2014	6:00:00	28.5	62.5	20.6
41	wk2	4/30/2014	12:00:00	39.5	35	21.2
42	wk2	4/30/2014	18:00:00	54	15	19.4
43	wk2	5/1/2014	0:00:00	28	61	19.8
44	wk2	5/1/2014	6:00:00	26	67.5	19.5
45	wk2	5/1/2014	12:00:00	37	38.5	20.5
46	wk2	5/1/2014	18:00:00	45	20	16.8
47	wk2	5/2/2014	0:00:00	32.5	44	18.7
48	wk2	5/2/2014	6:00:00	28.5	62	20.5
49	wk2	5/2/2014	12:00:00	37	41	21.6
50	wk2	5/2/2014	18:00:00	50.5	18.5	20
51	wk2	5/3/2014	0:00:00	27.5	74	22.4
52	wk2	5/3/2014	6:00:00	26	76	21.4
53	wk2	5/3/2014	12:00:00	31.5	61	23.1
54	wk2	5/3/2014	18:00:00	34.5	47.5	21.7
55	wk2	5/4/2014	0:00:00	25.5	72	20.1
56	wk2	5/4/2014	6:00:00	23.5	83.5	20.5
57	wk2	5/4/2014	12:00:00	32	53.5	21.4
58	wk2	5/4/2014	18:00:00	48.5	23	21.9
59	wk2	5/5/2014	0:00:00	29.5	55.5	19.7
60	wk2	5/5/2014	6:00:00	27	68.5	20.7
61	wk2	5/5/2014	12:00:00	37	42	21.9
62	wk2	5/5/2014	18:00:00	40.5	31	20.1
63	wk4	5/6/2014	0:00:00	27	72	21.5
64	wk4	5/6/2014	6:00:00	22.5	98	22.2
65	wk4	5/6/2014	12:00:00	31.5	59.5	22.6
66	wk4	5/6/2014	18:00:00	45	28	22.2
67	wk4	5/7/2014	0:00:00	28	66.5	21.2
68	wk4	5/7/2014	6:00:00	24.5	83	21.4
69	wk4	5/7/2014	12:00:00	25.5	86.5	23.1
70	wk4	5/7/2014	18:00:00	41.5	36	23.4
71	wk4	5/8/2014	0:00:00	27	76.5	22.5
72	wk4	5/8/2014	6:00:00	23.5	89.5	21.7
73	wk4	5/8/2014	12:00:00	34.5	50	22.6
74	wk4	5/8/2014	18:00:00	40	37	22.5
75	wk4	5/9/2014	0:00:00	27.5	68.5	21.2
76	wk4	5/9/2014	6:00:00	25	84	22.1
77	wk4	5/9/2014	12:00:00	34.5	54.5	24
78	wk4	5/9/2014	18:00:00	46	23	19.9
79	wk4	5/10/2014	0:00:00	29.5	52	18.6

80	wk4	5/10/2014	6:00:00	27	60	18.6
81	wk4	5/10/2014	12:00:00	33.5	43.5	19.4
82	wk4	5/10/2014	18:00:00	34	42	19.3
83	wk4	5/11/2014	0:00:00	26.5	64.5	19.3
84	wk4	5/11/2014	6:00:00	25	68.5	18.8
85	wk4	5/11/2014	12:00:00	36	36	18.6
86	wk4	5/11/2014	18:00:00	48.5	13.5	13.5
87	wk4	5/12/2014	0:00:00	29	43.5	15.3
88	wk4	5/12/2014	6:00:00	26.5	56.5	17.1
89	wk4	5/12/2014	12:00:00	37	37.5	20.1
90	wk4	5/12/2014	18:00:00	48	14.5	14.2
91	wk4	5/13/2014	0:00:00	30	37.5	13.9
92	wk4	5/13/2014	6:00:00	28.5	55.5	18.7
93	wk4	5/13/2014	12:00:00	37	38.5	20.5
94	wk4	5/13/2014	18:00:00	29.5	52.5	18.8
95	wk4	5/14/2014	0:00:00	26	65.5	19
96	wk4	5/14/2014	6:00:00	25	66	18.2
97	wk4	5/14/2014	12:00:00	37	36.5	19.7
98	wk4	5/14/2014	18:00:00	38	24	13.9
99	wk4	5/15/2014	0:00:00	29	49.5	17.4
100	wk4	5/15/2014	6:00:00	27	42.5	13.2
101	wk4	5/15/2014	12:00:00	35	23.5	11.1
102	wk4	5/15/2014	18:00:00	45.5	11.5	8.8
103	wk4	5/16/2014	0:00:00	28.5	35.5	11.8
104	wk4	5/16/2014	6:00:00	25	42.5	11.4
105	wk4	5/16/2014	12:00:00	37.5	35	19.4
106	wk4	5/16/2014	18:00:00	50	12.5	13.4
107	wk4	5/17/2014	0:00:00	29.5	32	11.1
108	wk4	5/17/2014	6:00:00	27	49.5	15.5
109	wk4	5/17/2014	12:00:00	35	42	20.2
110	wk4	5/17/2014	18:00:00	47	15.5	14.4
111	wk4	5/18/2014	0:00:00	30	38	14.1
112	wk4	5/18/2014	6:00:00	27.5	54.5	17.5
113	wk4	5/18/2014	12:00:00	37.5	41.5	22.2
114	wk4	5/18/2014	18:00:00	53.5	13.5	17.3
115	wk4	5/19/2014	0:00:00	31	44.5	17.5
116	wk4	5/19/2014	6:00:00	26	65	18.9
117	wk4	5/19/2014	12:00:00	37	37.5	20.1
118	wk4	5/19/2014	18:00:00	40	30	19.1
119	wk6	5/20/2014	0:00:00	31.5	52	20.4
120	wk6	5/20/2014	6:00:00	27.5	54	17.4
121	wk6	5/20/2014	12:00:00	36.5	36	19
122	wk6	5/20/2014	18:00:00	42	26	18.5

123	wk6	5/21/2014	0:00:00	31.5	46.5	18.6
124	wk6	5/21/2014	6:00:00	27.5	70	21.5
125	wk6	5/21/2014	12:00:00	39	41	23.3
126	wk6	5/21/2014	18:00:00	48.5	14	14
127	wk6	5/22/2014	0:00:00	30	33.5	12.2
128	wk6	5/22/2014	6:00:00	28	66.5	21.2
129	wk6	5/22/2014	12:00:00	36.5	45	22.6
130	wk6	5/22/2014	18:00:00	52	13.5	16.2
131	wk6	5/23/2014	0:00:00	30	46	17.1
132	wk6	5/23/2014	6:00:00	27	52.5	16.5
133	wk6	5/23/2014	12:00:00	38	35.5	20.1
134	wk6	5/23/2014	18:00:00	49	12.5	12.7
135	wk6	5/24/2014	0:00:00	31.5	45	18.1
136	wk6	5/24/2014	6:00:00	27.5	59	18.8
137	wk6	5/24/2014	12:00:00	36.5	43	21.9
138	wk6	5/24/2014	18:00:00	53.5	16	20
139	wk6	5/25/2014	0:00:00	32.5	44	18.7
140	wk6	5/25/2014	6:00:00	29	59	20.2
141	wk6	5/25/2014	12:00:00	36	42.5	21.2
142	wk6	5/25/2014	18:00:00	48.5	22	21.2
143	wk6	5/26/2014	0:00:00	30.5	47	17.9
144	wk6	5/26/2014	6:00:00	25.5	72.5	20.2
145	wk6	5/26/2014	12:00:00	37.5	42	22.4
146	wk6	5/26/2014	18:00:00	53.5	14	17.9
147	wk6	5/27/2014	0:00:00	31.5	46	18.5
148	wk6	5/27/2014	6:00:00	26.5	66.5	19.7
149	wk6	5/27/2014	12:00:00	36.5	40.5	20.9
150	wk6	5/27/2014	18:00:00	49.5	18.5	19.2
151	wk6	5/28/2014	0:00:00	24.5	82	21.2
152	wk6	5/28/2014	6:00:00	24.5	78.5	20.5
153	wk6	5/28/2014	12:00:00	33.5	53.5	22.8
154	wk6	5/28/2014	18:00:00	43	28	20.5
155	wk6	5/29/2014	0:00:00	27	62.5	19.2
156	wk6	5/29/2014	6:00:00	24.5	78	20.4
157	wk6	5/29/2014	12:00:00	33	54.5	22.6
158	wk6	5/29/2014	18:00:00	43	31.5	22.5
159	wk6	5/30/2014	0:00:00	26.5	61.5	18.5
160	wk6	5/30/2014	6:00:00	24.5	73.5	19.4
161	wk6	5/30/2014	12:00:00	35.5	44.5	21.5
162	wk6	5/30/2014	18:00:00	51.5	19	21.2
163	wk6	5/31/2014	0:00:00	30	57	20.5
164	wk6	5/31/2014	6:00:00	26.5	75	21.7
165	wk6	5/31/2014	12:00:00	35.5	46.5	22.3

166	wk6	5/31/2014	18:00:00	52	20.5	22.9
167	wk6	6/1/2014	0:00:00	32	55.5	22
168	wk6	6/1/2014	6:00:00	25.5	63	17.9
169	wk6	6/1/2014	12:00:00	32.5	46.5	19.6
170	wk6	6/1/2014	18:00:00	46	23	19.9
171	wk6	6/2/2014	0:00:00	30.5	55	20.4
172	wk6	6/2/2014	6:00:00	26.5	66.5	19.7
173	wk6	6/2/2014	12:00:00	35.5	41.5	20.4
174	wk6	6/2/2014	18:00:00	52	18.5	21.2
175	wk8	6/3/2014	0:00:00	31.5	54	21.1
176	wk8	6/3/2014	6:00:00	22.5	84	19.7
177	wk8	6/3/2014	12:00:00	32.5	52.5	21.5
178	wk8	6/3/2014	18:00:00	47.5	24	21.8
179	wk8	6/4/2014	0:00:00	31	59.5	22.2
180	wk8	6/4/2014	6:00:00	26.5	70	20.6
181	wk8	6/4/2014	12:00:00	36	47	22.9
182	wk8	6/4/2014	18:00:00	49.5	20	20.5
183	wk8	6/5/2014	0:00:00	32.5	50	20.7
184	wk8	6/5/2014	6:00:00	28	70	22
185	wk8	6/5/2014	12:00:00	36.5	45	22.6
186	wk8	6/5/2014	18:00:00	42	28.5	20
187	wk8	6/6/2014	0:00:00	31.5	50	19.8
188	wk8	6/6/2014	6:00:00	25	59.5	16.6
189	wk8	6/6/2014	12:00:00	32	48.5	19.8
190	wk8	6/6/2014	18:00:00	43.5	26.5	20.1
191	wk8	6/7/2014	0:00:00	29.5	48.5	17.5
192	wk8	6/7/2014	6:00:00	27	68.5	20.7
193	wk8	6/7/2014	12:00:00	35.5	44	21.4
194	wk8	6/7/2014	18:00:00	41	32	21
195	wk8	6/8/2014	0:00:00	29.5	63	21.7
196	wk8	6/8/2014	6:00:00	26.5	72.5	21.1
197	wk8	6/8/2014	12:00:00	36	48	23.2
198	wk8	6/8/2014	18:00:00	51.5	20	22.1
199	wk8	6/9/2014	0:00:00	30	49.5	18.3
200	wk8	6/9/2014	6:00:00	27	57	17.8
201	wk8	6/9/2014	12:00:00	35	46.5	21.8
202	wk8	6/9/2014	18:00:00	46	24.5	20.9
203	wk8	6/10/2014	0:00:00	28	58	19
204	wk8	6/10/2014	6:00:00	22	90.5	20.4
205	wk8	6/10/2014	12:00:00	29	62	21
206	wk8	6/10/2014	18:00:00	42	29.5	20.5
207	wk8	6/11/2014	0:00:00	26.5	60	18.1
208	wk8	6/11/2014	6:00:00	24.5	74	19.6

209	wk8	6/11/2014	12:00:00	35.5	42	20.6
210	wk8	6/11/2014	18:00:00	50	19.5	20.5
211	wk8	6/12/2014	0:00:00	31	48	18.7
212	wk8	6/12/2014	6:00:00	27	70	21.1
213	wk8	6/12/2014	12:00:00	36.5	45.5	22.8
214	wk8	6/12/2014	18:00:00	46.5	24.5	21.3
215	wk8	6/13/2014	0:00:00	29.5	50.5	18.1
216	wk8	6/13/2014	6:00:00	26.5	65.5	19.5
217	wk8	6/13/2014	12:00:00	35.5	46.5	22.3
218	wk8	6/13/2014	18:00:00	50	20.5	21.3
219	wk8	6/14/2014	0:00:00	31.5	47	18.8
220	wk8	6/14/2014	6:00:00	26.5	59	17.8
221	wk8	6/14/2014	12:00:00	33.5	44.5	19.7
222	wk8	6/14/2014	18:00:00	47	23	20.7
223	wk8	6/15/2014	0:00:00	27.5	55	17.7
224	wk8	6/15/2014	6:00:00	24.5	68.5	18.3
225	wk8	6/15/2014	12:00:00	35	42.5	20.4
226	wk8	6/15/2014	18:00:00	49	21.5	21.2
227	wk8	6/16/2014	0:00:00	29.5	62	21.4
228	wk8	6/16/2014	6:00:00	26.5	76	21.9
229	wk8	6/16/2014	12:00:00	35.5	49	23.1
230	wk8	6/16/2014	18:00:00	23.5	88	21.4
231	wk10	6/17/2014	0:00:00	24	84	21.1
232	wk10	6/17/2014	6:00:00	23.5	88.5	21.5
233	wk10	6/17/2014	12:00:00	32.5	58.5	23.3
234	wk10	6/17/2014	18:00:00	49.5	23.5	23.1
235	wk10	6/18/2014	0:00:00	23	87.5	20.8
236	wk10	6/18/2014	6:00:00	23	90	21.3
237	wk10	6/18/2014	12:00:00	32.5	59.5	23.6
238	wk10	6/18/2014	18:00:00	39.5	41.5	24
239	wk10	6/19/2014	0:00:00	28	75	23.1
240	wk10	6/19/2014	6:00:00	24.5	78	20.4
241	wk10	6/19/2014	12:00:00	34.5	42	19.7
242	wk10	6/19/2014	18:00:00	50	21	21.7
243	wk10	6/20/2014	0:00:00	29.5	62.5	21.6
244	wk10	6/20/2014	6:00:00	26	79	22.1
245	wk10	6/20/2014	12:00:00	34	51.5	22.6
246	wk10	6/20/2014	18:00:00	48	25.5	23.2
247	wk10	6/21/2014	0:00:00	30.5	61	22.1
248	wk10	6/21/2014	6:00:00	26	67.5	19.5
249	wk10	6/21/2014	12:00:00	34.5	51.5	23
250	wk10	6/21/2014	18:00:00	47.5	26	23.1
251	wk10	6/22/2014	0:00:00	31	58.5	21.9

252	wk10	6/22/2014	6:00:00	27.5	72.5	22.1
253	wk10	6/22/2014	12:00:00	35.5	45	21.7
254	wk10	6/22/2014	18:00:00	43	31	22.2
255	wk10	6/23/2014	0:00:00	29	55	19
256	wk10	6/23/2014	6:00:00	24.5	59.5	16.1
257	wk10	6/23/2014	12:00:00	35	48	22.3
258	wk10	6/23/2014	18:00:00	43	30	21.7
259	wk10	6/24/2014	0:00:00	28	60	19.5
260	wk10	6/24/2014	6:00:00	24	75	19.3
261	wk10	6/24/2014	12:00:00	34.5	45.5	21
262	wk10	6/24/2014	18:00:00	51.5	17.5	19.9
263	wk10	6/25/2014	0:00:00	30	48.5	18
264	wk10	6/25/2014	6:00:00	26	65.5	19
265	wk10	6/25/2014	12:00:00	34.5	40.5	19.1
266	wk10	6/25/2014	18:00:00	52.5	17	20.2
267	wk10	6/26/2014	0:00:00	28	52.5	17.4
268	wk10	6/26/2014	6:00:00	25	58.5	16.3
269	wk10	6/26/2014	12:00:00	34	47.5	21.3
270	wk10	6/26/2014	18:00:00	48	24	22.2
271	wk10	6/27/2014	0:00:00	28	51.5	17.1
272	wk10	6/27/2014	6:00:00	25.5	65.5	18.6
273	wk10	6/27/2014	12:00:00	34.5	49	22.2
274	wk10	6/27/2014	18:00:00	48.5	23	21.9
275	wk10	6/28/2014	0:00:00	30.5	50	18.9
276	wk10	6/28/2014	6:00:00	23	80.5	19.5
277	wk10	6/28/2014	12:00:00	34	45.5	20.6
278	wk10	6/28/2014	18:00:00	23.5	88.5	21.5
279	wk10	6/29/2014	0:00:00	24	81.5	20.6
280	wk10	6/29/2014	6:00:00	22	97	21.5
281	wk10	6/29/2014	12:00:00	32	56.5	22.3
282	wk10	6/29/2014	18:00:00	47	28	23.9
283	wk10	6/30/2014	0:00:00	27	70.5	21.2
284	wk10	6/30/2014	6:00:00	24.5	87	22.2
285	wk10	6/30/2014	12:00:00	33	58.5	23.8
286	wk10	6/30/2014	18:00:00	48	27.5	24.5
287	wk12	7/1/2014	0:00:00	23.5	77	19.2
288	wk12	7/1/2014	6:00:00	22.5	90.5	20.9
289	wk12	7/1/2014	12:00:00	33	53	22.1
290	wk12	7/1/2014	18:00:00	50	22	22.4
291	wk12	7/2/2014	0:00:00	28.5	62.5	20.6
292	wk12	7/2/2014	6:00:00	25.5	81	22
293	wk12	7/2/2014	12:00:00	33	55.5	22.9
294	wk12	7/2/2014	18:00:00	45.5	27.5	22.4

295	wk12	7/3/2014	0:00:00	28.5	68	22
296	wk12	7/3/2014	6:00:00	26	83.5	23
297	wk12	7/3/2014	12:00:00	34	54	23.4
298	wk12	7/3/2014	18:00:00	25	89.5	23.2
299	wk12	7/4/2014	0:00:00	23	87.5	20.8
300	wk12	7/4/2014	6:00:00	23	90.5	21.4
301	wk12	7/4/2014	12:00:00	31.5	58.5	22.4
302	wk12	7/4/2014	18:00:00	44.5	30	23
303	wk12	7/5/2014	0:00:00	27.5	67.5	20.9
304	wk12	7/5/2014	6:00:00	24.5	78.5	20.5
305	wk12	7/5/2014	12:00:00	32	56.5	22.3
306	wk12	7/5/2014	18:00:00	43	32.5	23
307	wk12	7/6/2014	0:00:00	27.5	68.5	21.2
308	wk12	7/6/2014	6:00:00	25	76	20.5
309	wk12	7/6/2014	12:00:00	20	96.5	19.4
310	wk12	7/6/2014	18:00:00	33.5	50.5	21.8
311	wk12	7/7/2014	0:00:00	23.5	83	20.4
312	wk12	7/7/2014	6:00:00	21.5	92	20.1
313	wk12	7/7/2014	12:00:00	31	64.5	23.5
314	wk12	7/7/2014	18:00:00	44	34.5	24.8
315	wk12	7/8/2014	0:00:00	25.5	80.5	21.9
316	wk12	7/8/2014	6:00:00	24.5	87	22.2
317	wk12	7/8/2014	12:00:00	33	59.5	24
318	wk12	7/8/2014	18:00:00	24.5	75.5	19.9
319	wk12	7/9/2014	0:00:00	22.5	88.5	20.5
320	wk12	7/9/2014	6:00:00	21.5	93	20.3
321	wk12	7/9/2014	12:00:00	31	62.5	23
322	wk12	7/9/2014	18:00:00	37.5	44	23.2
323	wk12	7/10/2014	0:00:00	26.5	77	22.1
324	wk12	7/10/2014	6:00:00	23	92	21.6
325	wk12	7/10/2014	12:00:00	32.5	60	23.7
326	wk12	7/10/2014	18:00:00	45	32	24.5
327	wk12	7/11/2014	0:00:00	28	69.5	21.9
328	wk12	7/11/2014	6:00:00	25	84.5	22.2
329	wk12	7/11/2014	12:00:00	33.5	58.5	24.2
330	wk12	7/11/2014	18:00:00	47.5	28.5	24.6
331	wk12	7/12/2014	0:00:00	22.5	93.5	21.4
332	wk12	7/12/2014	6:00:00	22.5	90.5	20.9
333	wk12	7/12/2014	12:00:00	32.5	60.5	23.9
334	wk12	7/12/2014	18:00:00	29	63	21.2
335	wk12	7/13/2014	0:00:00	21.5	89	19.6
336	wk12	7/13/2014	6:00:00	20.5	95	19.7
337	wk12	7/13/2014	12:00:00	31	63	23.1

338	wk12	7/13/2014	18:00:00	47	29.5	24.8
339	wk12	7/14/2014	0:00:00	26.5	78	22.3
340	wk12	7/14/2014	6:00:00	23.5	87.5	21.3
341	wk12	7/14/2014	12:00:00	34.5	51.5	23

Appendix III: Shade and Sun Mean Microclimatic Conditions' Data

Shade				**Sun**		
Temp	**Humidity**	**Dew**	**WAS**	**Temp**	**Humidity**	**Dew**
29.64	61.43	20.98	2	35.28	44.87	19.45
27.05	74.89	21.96	4	33.10	47.08	18.29
32.01	49.31	19.26	6	35.29	45.67	19.77
30.54	51.05	18.30	8	33.79	50.10	20.48
31.95	50.16	19.60	10	33.04	55.09	21.09
30.83	54.84	20.30	12	29.85	67.72	22.02

Appendix IV: Shade and Sun Emergence of *Jatropha curcas* Seedlings' Data

Days After Sowing	**Number of Emergence (Shade)**	**Number of Emergence (Sun)**
Day 4	25	32
Day 5	34	38
Day 6	39	43
Day 7	41	44
Day 8	41	44

Appendix V: Shade and Sun Mean Early Growth Characteristics of *Jatropha curcas* Seedlings' Data

Characters	**Treatments**	**2 WAS**	**4 WAS**	**6 WAS**	**8 WAS**	**10 WAS**	**12 WAS**
HT(cm)	Shade	13.5	16.7	20	24.1	27.1	38.3
HT(cm)	Sun	12.7	19	27.9	39.1	51.7	70.2
SD(cm)	Shade	0.5	0.5	0.6	0.7	0.8	1.1
SD(cm)	Sun	0.5	0.6	0.7	1.2	1.4	1.8
LA(cm^2)	Shade	28.4	34.8	38.8	39.9	41.7	43.2
LA (cm^2)	Sun	21.8	35.7	42.1	45.5	48.8	61.5
LC	Shade	3.2	5.2	8.4	10.6	13.4	18.2
LC	Sun	3.4	5.8	11.4	15.8	21.4	32.2
FW (g)	Shade	4.9	7.9	14.2	23	30	69.7
FW(g)	Sun	4.9	13.6	28.6	71.1	136.4	259.6
DW(g)	Shade	0.4	0.8	1.8	3.1	6.5	13.8
DW(g)	Sun	0.4	1.5	3.9	10.9	31.9	55.9
CGR(g/wk)	Shade	0.2	0.2	0.5	0.7	1.7	3.7
CGR (g/wk)	Sun	0.2	0.6	1.2	3.5	10.5	12

Appendix VI: Shade and Sun Correlation Results between Microclimatic Conditions and Number of days to Seedlings Emergence

	Temp. (^oC)	Humidity (%)	Dew (%)
Seedling Emergence (Shade)	.602	-.705	-.888*

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

	Temp (^oC)	Humidity (%)	Dew (%)
Seedling Emergence (Sun)	.685	-.718	-.943*

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix VII: Shade Correlation Result between Microclimatic Conditions and Early Growth Characteristics of *Jatropha curcas* Seedlings

	HT (cm)	SD (cm)	LA (cm^2)	LC	FW (g)	DW (g)	CGR (g/wk)	Temp. (^oC)	Humidity (%)	Dew (%)
HT (cm)	1									
SD (cm)	.991**	1								
LA (cm^2)	.860*	.797	1							
LC	.989**	.974**	.910*	1						
FW (g)	.981**	.990**	.752	.945**	1					
DW (g)	.973**	.988**	.737	.943**	.992**	1				
CGR (g/wk)	.881*	.906*	.559	.807	.952**	.929**	1			
Temp. (^oC)	.451	.470	.550	.543	.373	.384	.380	1		
Humidity (%)	-.458	-.467	-.575	-.548	-.367	-.354	-.341	-.970**	1	
Dew (%)	-.321	-.293	-.548	-.413	-.196	-.146	-.115	-.768	.894*	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix VIII: Sun Correlation Result between Microclimatic Conditions and Early Growth Characteristics of *Jatropha curcas* Seedlings

	HT (cm)	SD (cm)	LA (cm^2)	LC	FW (g)	DW (g)	CGR (g/wk)	Temp. (^oC)	humidity (%)	Dew (%)
HT (cm)	1									
SD (cm)	.989**	1								
LA (cm^2)	.949**	.917*	1							
LC	.998**	.981**	.949**	1						
FW (g)	.973**	.960**	.885*	.977**	1					
DW (g)	.963**	.947**	.860*	.965**	.995**	1				
CGR (g/wk)	.977**	.972**	.891*	.981**	.998**	.989**	1			
Temp. (^oC)	-.833*	-.829*	-.797	-.831*	-.896*	-.887*	-.805*	1		
Humidity (%)	.946**	.935**	.861*	.951**	.992**	.986**	.921**	-.940**	1	
Dew (%)	.926**	.928**	.800	.931**	.904*	.896*	.897*	-.634	.851*	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).