# EFFECT OF DEFICIT IRRIGATION AND MULCH MATERIALS ON CROP YIELD AND WATER USE OF CUCUMBER (*Cucumis sativus L.*) IN SAMARU, NIGERIA.

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BY

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ZARIA, NIGERIA

JANUARY, 2018

## DECLARATION

I declare that the work in this Dissertation entitled "Effect of Deficit Irrigation and Mulch Materials on Yield and Water Use of Cucumber (*Cucumis sativus L.*) In Samaru, Nigeria" has been carried out by me in the Department of Agricultural and Bioresources Engineering, Ahmadu Bello University, Zaria, under the supervision of Prof. M.K. Othman and Prof. A.A. Ramalan. 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.

| | | |
|---|---|---|
| Nura Yahaya MUSA | …… | …….. |
| Student | Signature | Date |

## CERTIFICATION

This Dissertation entitled "Effect of Deficit Irrigation and Mulch Materials on Yield and Water Use of Cucumber (*Cucumis sativus L.*) In Samaru, Nigeria" by Nura Yahaya MUSA, meets the regulations governing the award of degree of Master of Science (Agricultural and Bioresources Engineering) of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

| | | |
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## DEDICATION

This work is dedicated to my late mum Hajiya Halima Abubakar for her sacrifice, love and support to see me succeed in life. May Allah have mercy on her soul. Amen.

## ACKNOWLEDGEMENTS

Glory and Honours be to Allah (S.W.A) the Most High, with Whose infinite mercy; make this programme a successful, reality and completed one.

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## ABSTRACT

The study was conducted during the dry season in 2016 at the Irrigation Research farm of Institute for Agricultural Research, Samaru, Zaria, to determine the effect of deficit irrigation and mulch on yield and water use of Cucumber crop. The experiment consisted of four levels of moisture depletion at 0%, 25%, 50%, and 75% ($I_{100}$, $I_{75}$, $I_{50}$, and $I_{25}$) of irrigation water application depths and three mulch types Rice straw mulch; Black polythene mulch, and No mulch (RSM, BPM, and NM) respectively. This was replicated three times laid in a split plot design (SPD). The irrigation water was allocated to the main plot, while mulch material was assign at the sub-plots. Water was applied to the basin using a PVC pipe of 7.5 cm diameter and 50 cm length to serve as an orifice. The soil moisture was measured and monitored during the growing season of the crop, through an access tubes installed in each basin at three different depths of 0 – 15, 15 – 30, 30 – 45 cm coupled with theta probe moisture instrument. The result showed that application of 25% water deficit ($I_{75}$), combined with rice straw mulch gives the highest yield of 14.60 t/ha when compared to irrigation at 25% water deficit ($I_{75}$) with Black polythene, and No Mulch with the same irrigation level. The yield obtained from the treatments ranges from 4.33 t/ha to 14.60 t/ha. The least yield was obtained from the treatment ($I_{25}$NM), while the highest yield was obtained from the treatment ($I_{75}$RSM). The highest crop water use efficiency (CWUE) and irrigation water use efficiency were 93.7 kg/ha/mm and 90.3 kg/ha/mm at 0% level of moisture depletion, respectively, while the least is at 25% moisture depletion with value of 65.3 kg/ha/mm and 65.5 kg/ha/mm, respectively. The yield response factor (Ky) for the total growing season obtained for RSM was 1.013; for BPM was 1.243 and for NM was 0.549, respectively. The study showed that crop water use (CWU) of the Cucumber crop decreased with increase in irrigation

deficit. The Kc values ranges from 0.34 – 0.48 for initial stage, 0.43 – 0.66 for development stage, 0.30 – 0.85 for mid-season stage, and 0.30 – 0.69 for late season stage. From the results obtained it shows that applying management methods such as the use of mulch cover for better use of water resources and in order to minimize water stress appears to be essential. Also the results showed that the interaction effects of irrigation and mulch treatments were significant on yield, length, weight and number of fruits.

## TABLE OF CONTENTS


| Content | | Page |
|---|---|---|
| TITLE PAGE | | i |
| DECLARATION | | ii |
| CERTIFICATION | | iii |
| DEDICATION | | iv |
| ACKNOWLEDGEMENTS | | v |
| ABSTRACT | | vi |
| TABLE OF CONTENTS | | viii |
| LIST OF FIGURES | | xi |
| LIST OF TABLES | | xii |
| LIST OF PLATES | | xiii |
| LIST OF APPENDICES | | xiv |
| ABBREVIATIONS | | xv |
| UNITS | | xvi |
| **CHAPTER ONE** | | |
| **1.0** | **INRODUCTION** | 1 |
| 1.1 | Background of the Study | 1 |
| 1.2 | Statement of the Problem | 3 |
| 1.3 | Justification | 4 |
| 1.4 | Aim and Objectives of the Study | 6 |
| 1.4 | The objective of the study | 6 |

**CHAPTER TWO**


| | | |
|---|---|---|
| **2.0** | **REVIEW OF LITERATURE** | 7 |
| 2.1 | Deficit Irrigation | 7 |
| 2.1.1 | Irrigation depth | 9 |
| 2.2 | Effect of Mulch Material on Crop Production | 10 |
| 2.2.1 | Advantages of mulch | 11 |
| 2.2.2 | Organic mulch | 11 |
| 2.2.3 | Inorganic mulch | 12 |
| 2.3 | Irrigation Water Requirement of Cucumber | 13 |
| 2.4 | Water Use Efficiency of Cucumber | 14 |
| 2.5 | Irrigation Scheduling | 16 |
| 2.6 | Crop Yield and Water Use | 16 |
| 2.6.1 | Crop Coefficient | 17 |
| 2.7 | Reference Crop Evapotranspiration | 17 |
| 2.7.1 | Crop evapotranspiration | 18 |
| 2.8 | Soil Moisture Content | 19 |
| 2.9 | Characteristics of Experimental Crop | 19 |


**CHAPTER THREE**


| | | |
|---|---|---|
| **3.0** | **MATERIALS AND METHODS** | 21 |
| 3.1 | Description of the Study Area | 21 |
| 3.2 | Treatments and Experimental Design | 21 |
| 3.3 | Experimental Plot Size | 21 |
| 3.4 | Water Application | 24 |
| 3.5 | Placement of Mulch Materials | 24 |
| 3.6 | Soil Data Analysis | 25 |

**3.7 Cultural Practice** 25

3.7.1 Measurement of soil moisture 27

3.7.2 Determination of actual evapotranspiration ($ET_a$) 27

3.7.3 Determination of crop water and irrigation water use efficiency 27

3.8 Crop Data Yield Parameters and Data Analysis 28

3.9 Yield Response Factor to Water Deficit 28

3.10 Crop Coefficient 28

3.11 Crop Evapotranspiration 29

3.12 Data Analysis 29

**CHAPTER FOUR**

**4.0 RESULTS AND DISCUSSION** 30

4.1 Cucumber Yield and Yield Parameter 30

4.2 Effect of Irrigation and Mulch on Irrigation Water Depth 34

4.3 Effect of Irrigation and Mulch on Crop Water Use and Irrigation Water Use Efficiency 38

4.4 Yield Response Factor 41

4.5 Soil Moisture Deletion Trend 42

4.6 Crop coefficient 52

**CHAPTER FIVE**

**5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS** 54

5.1 Summary 54

5.2 Conclusion 55

5.3 Recommendations 56

**REFERENCES** 57

**APPENDICES**


Appendix I Analysis of variance table for yield of cucumber 65

Appendix II Analysis of variance table for number of fruit of cucumber 65

Appendix III: Analysis of variance table for fruit length of cucumber 65

Appendix IV: Analysis of variance table for fruit circumference of cucumber 66

Appendix V: Analysis of variance table for marketable fruit of cucumber 66

Appendix VI: Analysis of variance table for unmarketable fruit of cucumber 66

Appendix VII: Average water applied (mm) in weeks after planting 69

## LIST OF FIGURES


| Figure | | Page |
|---|---|---|
| Figure 1: | Sketch of the field layout | 23 |
| Figure 2: | Yield response factor (Ky) of the rice straw mulch treatment | 44 |
| Figure 3: | Yield response factor (Ky) of the black polythene mulch treatment | 44 |
| Figure 4: | Yield response factor (Ky) of the no - mulch treatment | 45 |
| Figure 5: | Moisture depletion Trend of cucumber at different soil depth, irrigated at 100% with RSM | 46 |
| Figure 6: | Moisture depletion Trend of cucumber at different soil depth, irrigated at 100% with BPM | 46 |
| Figure 7: | Moisture depletion Trend of cucumber at different soil depth, irrigated at 100% with NM | 47 |
| Figure 8: | Moisture depletion Trend of cucumber at different soil depth, irrigated at 75% with RSM | 47 |
| Figure 9: | Moisture depletion Trend of cucumber at different soil depth, irrigated at 75% with BPM | 48 |
| Figure 10: | Moisture depletion Trend of cucumber at different soil depth, irrigated at 75% with NM | 48 |
| Figure 11: | Moisture depletion Trend of cucumber at different soil depth, irrigated at 50% with RSM | 49 |
| Figure 12: | Moisture depletion Trend of cucumber at different soil depth, irrigated at 50% with BPM | 49 |
| Figure 13: | Moisture depletion Trend of cucumber at different soil depth, irrigated at 50% with NM | 50 |
| Figure 14: | Moisture depletion Trend of cucumber at different soil depth, irrigated at 25% with RSM | 50 |
| Figure 15: | Moisture depletion Trend of cucumber at different soil depth, irrigated at 25% with BPM | 51 |
| Figure 16: | Moisture depletion Trend of cucumber at different soil depth, irrigated at 25% with NM | 51 |

## LIST OF TABLES


| Table | | Page |
|---|---|---|
| Table 3.1: | Average Monthly Weather Data for Samaru, (Jan-May 2011) Irrigation Cropping Season | 22 |
| Table 3.2: | Description of the Experimental Treatment | 22 |
| Table 3.3: | Physical Properties of Soils at Various Depths at I-A-R Irrigation Research Farm | 26 |
| Table 4.1a: | Total Yield and Number of Cucumber Fruit | 31 |
| Table 4.1b: | water use and water applied for cucumber crop | 32 |
| Table 4.2: | Effect of Irrigation and Mulch on Yield and Number of Cucumber | 34 |
| Table 4.3: | Effect of irrigation and mulch on irrigation water depth and seasonal water use of cucumber | 36 |
| Table 4.4: | Interaction of Irrigation and Mulch on Irrigation Water Depth | 37 |
| Table 4.5: | Interaction Effect of Irrigation and Mulch on Seasonal Water Use | 38 |
| Table 4.6: | Effect of Irrigation and Mulch on Water Use Efficiency and Irrigation Water Use Efficiency | 39 |
| Table 4.7: | Interaction Effect of Irrigation and Mulch on Crop Water Use Efficiency | 40 |
| Table 4.8: | Interaction Effect of Irrigation and Mulch on Irrigation Water Use efficiency | 41 |
| Table 4.9: | crop coefficient values for cucumber crop during 2016 dry season | 53 |

## LIST OF PLATES


| Plate | | Page |
|---|---|---|
| Plate I: | Thetaprobe Instrument, taking reading on the field | 70 |
| Plate II: | Cucumber plant with rice straw mulch | 71 |
| Plate III: | Experimental Field layout with treatment | 72 |

## ABBREVIATIONS

IWUE = Irrigation Water Use Efficiency

WUE = Water Use Efficiency

DI = Deficit Irrigation

Kc = Crop Coefficient

FAO = Food and Agriculture Organization

Ky = Crop Response Factor

HYVs = High Yield Varieties

ER = effective Rainfall

S = soil Profile contribution

RCBD = randomize complete block design

SPD = split plot design

NM = No Mulch

BPM = black polythene mulch

RSM = rice straw mulch

Fc = Field capacity

Pwp = permanent wilting point

ANOVA = analysis of variance

DMRT = Duncan multiple range test

**UNITS**

mm = millimeter

cm = centimeter

Kg = kilogram

t/ha = tone per hectare

ha = hectare

g/cm = gram per centimeter

$cm^2$ = square meter

$cm^3$ = cubic meter

$^oc$ = degree centigrade

m/sec = meter per second

hr = hour

m = meter

kPa = kilopascal

# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background of the Study

Cucumber (*Cucumis sativa L*) is one of the monoecious annual crops in the Cucurbitaceae family that has been cultivated by man for over 3, 000 years (Adetula and Denton, 2003; Okonmah, 2011). With respect to economic importance, it ranks fourth after tomatoes, cabbage and onion in Asia (Eifediyi and Remison, 2011), and second after tomato in Western Europe (Eifediyi and Remison, 2011), though its place has not been ranked in tropical Africa because of limited use. Soft and succulent, the vegetable crop is cherished by man and eaten in salads or sliced into stew in tropical regions. Its juice is often recommended as source of silicon to improve the health and complexion of the skin (Duke, 1997). Cucumber is a very good source of vitamins A, C, K, and B6, potassium, pantothenic acid, magnesium, phosphorus, copper and manganese (Vimala *et al.*, 1999). The ascorbic acid and caffeic acid contained in cucumber help to reduce skin irritation and swollen (Okonmah, 2011).

Deficit irrigation can play an important role in increasing water use efficiency (WUE) and reduced amount of irrigation. Deficit irrigation generally refers to fully irrigated crops where water is reduced or withheld during certain growth stages. One of important method to save irrigation water and increase WUE is deficit irrigation (DI) (Patane and Casentino, 2009), in which crops deliberately allowed some degree of deficit irrigation through the whole growth stage or at certain stages of the growth (Topcu *et.al*, 2007). The adoption of deficit irrigation required the knowledge of crop evapotranspiration (ETc), crop response to water deficit, critical stages of growth under water deficit and economic impacts of yield reduction. The development of new

irrigation scheduling techniques such as deficit irrigation and identifying the sensitive crop growth stage to water stress is one way to enhance crop productivity with less water (Bekele and Tilahun, 2007).

One of the major factors that hinder all year production of vegetable is the inadequate or no water supply to the crops during the dry season, especially in the semi-arid area of Nigeria. Unfortunately, it is more profitable to grow vegetable during this dry period (Ojo *et al*., 2011) reason being realization of higher quality product due to low disease pressure. So deficit irrigation can serve as a useful tool to improve irrigation management in arid and semiarid area (Holzapfel *et al.*, 1988).

Mulch conserves soil moisture, retained heat as well as it suppresses weed growth (Sharfuddin and Ssiddique, 1985; Ahmad *et al*., 2007). In addition to weeds control, mulch increase soil temperature, allow early plant harvest in the season. Mulch has been used in many forms for years with excellent results for the production of early, high quality vegetables. Mulch decrease watering frequency and prevent fertilizers from leaching by retaining soil moisture, saves time and money. Mulch has a distinct advantage for increase crop production. The practice conserves moisture by reducing the amount of soil water lost through evaporation, maintains soil uniform temperature, minimize soil erosion and compaction from heavy rains and aid in water penetration Mulching involves the use of materials to cover the cropped soil surface with the aim of reducing evaporation, conserving soil moisture, modifying soil temperature, structure and improving aeration (Plauborg *et al*., 1996, Hassan, 1996).

## 1.2 Statement of Problem

The growing increase of water scarcity and competition for water resources are major threat to agriculture in arid and semi-Arid region of Nigeria. Water scarcity is gradually becoming a constraint to agricultural production. Improper irrigation management leads to a number of plant disorders and diseases, in a situation of under irrigation or over irrigation both of which have adverse effects on crop yield. Under condition of limited water application, crop production is adversely affected by reduction in yield (Itier, 1996). Under limited water supply conditions, farmers tend to increase irrigation interval. Balancing the supply and demand of water is a critically challenging issue facing farmers in most part of arid and semi-arid region of Nigeria. Samaru in Kaduna state of Nigeria located within this region is similarly facing these challenges. Poor irrigation and water management are generally responsible for inefficient irrigation, leading to water wastage, and wastage of resources and pollution of the surface in the study area (Esfandiari and Maheshwari, 2001).

The current changes in weather bring with them an evident fluctuation in temperatures and also a relatively irregular and random distribution of moisture during the vegetation period of field crops. Therefore a study of plants' adaptation to a water deficit is ever more topical, as the water deficit leads to a fall in the uptake of nutrients, a restriction on photosynthesis, dry matter formation, the amount and quality of the yield (Hniličkа *et al*., 2007). In response to water deficit, stomata tend to close reducing leaf conductance that ultimately affects leaf photosynthesis (Faver *et al*., 1996). Under water stress or temperature stress, overall dry matter accumulation in cucumber plants is decreased (Hniličkova *et al*., 2002); expansion of leaf blades and plant growth is reduced, thereby promoting stunted growth (Gerik *et al*., 1996).

Cucumber is crops, requires more water than grain crops (Li and Wang, 2000). Mao *et al*. (2003) found that fresh fruit yields of cucumber were highly affected by the total volume of irrigation regimes were those that had water deficiencies during fruiting stages. Variation in soil moisture in the root zone from beginning to end of growing season will be small under irrigation due to the small volume of wetted soil (Kamal *et al*., 2009). Cucumber (*Cucumis sativus* L.) is one of the most popular vegetables cultivated in world. According to Buchtova (2011) grown cucumbers in the total area of 367 ha, of which 99 ha of cucumbers and gherkins 268 ha in 2011. The average yield per hectare of gherkins in 2010 was 21.48 t and cucumber 14.58 t.

The knowledge gap remains as to the effect of growth stage deficit irrigation tolerance limit for cucumber crop under different soil types, climatic condition, different methods of administering deficit irrigation for given locations and the corresponding impact on yield, soil water balance and water productivity of such locations. As the region is increasingly becoming dependent on the production of irrigated lands, irrigated agriculture faces serious challenges that threaten its sustainability. It is necessary to make efficient use of water and bring more area under irrigation with the same available water resources.

### 1.3 Justification

Efficient irrigation is obtained by filling the crop root zone at each irrigation, applying water uniformly and minimizing runoff (Yonts *et. al*., 2003). According to Isma'il and Ozawa (2009), in arid and semi arid as well as tropical regions, water shortage is a normal phenomenon and seriously limits the agricultural potential. Therefore, it is important for the available water to be used in the most efficient way. Proper irrigation regime and the use of proper method of irrigation can play a major role in increasing the water use efficiency and the productivity by applying the required

amount of water when it is needed (Bekele and Tilahun, 2007). One of the more feasible solution is the use of management of water for irrigation purposes. Studies are needed to increase the efficient use of the available water in crop production in irrigated agriculture. Since, the combination of regulated deficit irrigation with mulch is one way among others that can improve crop production without adversely affecting the yield of the crop, then it should be encourage in agricultural production. The development of new irrigation scheduling techniques such as deficit irrigation and identifying the sensitive crop growth stage to water stress is one way to enhance crop productivity with less water (Bekele and Tilahun, 2007).

Cucumber (*Cucumis sativus*) originates in southern Asia, but a large number of cultivars have been developed and are grown worldwide. It is a widely cultivated plant of the family Cucurbitaceae (Wehner and Guner, 2004). Cucumbers are used widely in a wide variety of salads. Due to the continue realization of the importance of fruits in our diets and the overwhelming importance of cucumber's health benefits along with skin care ; there is increasing demand for the product in Nigeria. International trade in 2002 amounted to 1.5 million tons, with Mexico, the Netherlands and Spain as the main exporters; international trade from African countries is modest and unrecorded. The demand for the product locally is far overwhelming accounting for its high cost in the market and a worthwhile Agribusiness with high degree of turnover over 200%.

The research is to offer a practical tool for selecting the most appropriate mulch and irrigation combination, yield response factor and Kc values for water balance irrigation schedulling which result in efficient irrigation. Also the study will come up with the appropriate way of applying water to the crop without causing adverse effect

on the yield and as well as wastage of water and polluting the environment. FAO (2005) stated that cucumber as a commercial vegetable crop; its cultivation is confined to the drier Savanna region of Nigeria. It is a crop with high economic value and is grown and traded for export. With respect to economic importance, it ranks fourth after tomatoes, cabbage and onion in Asia (Eifediyi and Remison, 2010), and second after tomato in Western Europe, though its place has not been ranked in tropical Africa because of limited use.

## 1.4 Aim and Objectives

The aim of the study is to evaluate the effects of deficit irrigation and mulch material on yield and water use efficiency of irrigated Cucumber.

The Objectives are to:

i. determine the Water use efficiency of the crop under deficit irrigation and mulch application.
ii. establish crop coefficient (Kc) values for irrigated Cucumber Crop under deficit irrigation and mulch condition for all the growth stages of the crop.
iii. determine the yield response factor of Cucumber under different deficit irrigation and mulch condition.

# CHAPTER TWO

# 2.0 REVIEW OF LITERATURE

## 2.1 Deficit Irrigation

Deficit irrigation is a scheduling method where irrigation is purposefully carried out not to fully meet crops water requirements and the plants are forced to extract soil moisture beyond readily available water in the plant root zone (Igbadun *et al.*, 2008). Deficit irrigation practices differ from traditional water supplying practices. The manager needs to know the level of transpiration deficiency allowable without significant reduction in crop yields. The main objective of deficit irrigation is to increase the Water Use Efficiency (WUE) of a crop by eliminating irrigations that have little impact on yield. The resulting yield reduction may be small compared with the benefits gained through diverting the saved water to irrigate other crops for which water would normally be insufficient under traditional irrigation practices. Before implementing a deficit irrigation program, it is necessary to know crop yield responses to water stress, either during defined growth stages or throughout the whole season (Kirda and Kanber, 1999). High-yielding varieties (HYVs) are more sensitive to water stress than low-yielding varieties; for example, deficit irrigation had a more adverse effect on the yields of new maize varieties than on those of traditional varieties (FAO, 1979). Crops or crop varieties that are most suitable for deficit irrigation are those with a short growing season and are tolerant to drought (Stewart and Musick, 1983).

In order to ensure successful deficit irrigation, it is necessary to consider the water retention capacity of the soil. In sandy soils plants may undergo water stress faster under deficit irrigation, than plants in deep soils of fine texture which may have ample

time to adjust to low soil water metric pressure, and may remain unaffected by low soil water content. Therefore, success with deficit irrigation is more probable in finely textured soils. Under deficit irrigation practices, agronomic practices may require modification, e.g. decrease plant population, apply less fertilizer, adopt flexible planting dates, and select shorter-season varieties. Deficit irrigation has been widely studied and practiced for improving crop yield and increasing irrigation water use efficiencies. (English *et al.,* 1996; Zhang *et.al.*, 1999; Wang *et al.*, 2001).

Doorenbos and Kassam (1979) stated that in order to quantify the effect of water stress, it is necessary to derive a relationship between the relative yield decrease and relative evapotranspiration deficits. Thus a relationship was given as presented in Eq. 2.1

$$(1 - \frac{Ya}{Ym}) = Ky\ (1 - \frac{ETa}{ETm}) \quad \text{.....2.1}$$

Where Ya and Ym are the actual and maximum yield in t/ha.

ETa and ETm are the actual and maximum evapotranspiration in mm

Ky is the yield response factor representing the effect of a reduction in evapotranspiration on yield losses.

The yield response factor (Ky) captures the essence of the complex linkages between production and water use by a crop, where many biological, physical and chemical processes are involved. The relationship has shown a remarkable validity and allowed a workable procedure to quantify the effects of water deficits on crop yield.

The Ky values are crop specific and vary over the growing season according to crop growth stages with:

Ky >1: crop response is very sensitive to water deficit with proportional larger yield reductions when water use is reduced because of stress.

Ky <1: crop is more tolerant to water deficit, and recovers partially from stress, exhibiting less than proportional reductions in yield with reduced water use.

Ky =1: yield reduction is directly proportional to reduced water use.

### 2.1.1 Irrigation depth

Depth of irrigation is a function of the water retentive capacity of the root zone soil and the extent of soil water deletion at time of irrigation. It refers to the depth of which the applied water would cover an area. The net depth of irrigation is decided by the amount of water required to bring the soil water content just before irrigation to field capacity in the root zone soil (Majundar, 2006, Michael, 1978). The water content of soil just before irrigation must be known to calculate the net depth of water required to be applied. It is calculated by the equation 2.2.

$$dn = \sum_{i}^{n} \frac{M1i - M2i}{t} Di \times Bdi \quad \text{.....2.2}$$

Where;

dn = net depth of water to be applied or net irrigation, cm

$M_{1i}$ = soil water at the time of first sampling in the i-th layer

$M_{2i}$ = soil water at the time of first sampling in the i-th layer

Di = depth of i-th layer of soil in the root zone cm

B*di* = bulk density of soil, g/cm$^3$

$$Dg = \frac{dn}{Ea} \quad \text{.....2.3}$$

The amount of water to be applied is obtained using the relation:

$$V = dg \times A \quad \text{.....2.4}$$

Where;

V = volume of water to be applied, m3

dg = depth of water to be applied, m

A = area to be irrigated, m2

Application time is obtained using the relation:

$t = (\frac{dg \times A}{Q})$……..2.5

Where:

t = Application time, seconds

## 2.2 Effect of Mulch Material on Crop Production

Mulching in general is a beneficial practice for crop production. Mulch conserves soil moisture, retained heat as well as it suppresses weed growth (Ahmad *et al*., 2007; Sharfuddin and Ssiddique, 1985).The greatest benefit from plastic mulch is that the soil temperature in the planting bed is raised, promoting faster crop development and earlier harvest. Black plastic mulch can give a harvest earlier by some 7-14 days. Soil water loss is reduced under plastic mulch. As a result, more uniform soil moisture is maintained and irrigation frequency can be reduced. The growth of plants on mulch can be twice that of plants in unmulched soil. Black mulches will reduce light penetration to the soil. Weeds cannot generally survive under such mulch. Fertilizer beneath the mulch is not lost by leaching, so that fertilizers are optimally used and not wasted. The soil under plastic mulch remains loose, friable and well-aerated. Roots have access to adequate oxygen, and microbial activity is enhanced. (Black 1980, Lancaster *et al*. 1987, Conway *et al*. 1989 and Lamont *et al*.,1990).

Mulching is the process or practice of covering the soil/ground to make more favorable condition for plant growths, development and efficient crop production. Mulch technical term means covering of soil, while natural mulches such as leaf, stray, dead leaves and compost have been used for centuries, during the last 60 years the advent of synthetic materials has altered the method and benefit of mulching. It therefore prevent directs evaporation of moisture from the soil and thus limit the water losses and soil erosion over the surface.

### 2.2.1 Advantages of mulching

• It prevents the direct evaporations of moisture from the soil and thus limits the water losses and conserves moisture.

• Mulch can facilitate fertilizer placement and reduce the loss of plant nutrient through hatching. • Mulching can provide a barrier to soil pathogens (Dalorima et.at, 2014).

### 2.2.2 Organic mulch

Organic mulches are derived from plant and animal materials such as straw, hay, peanut hulls, leaf mold, compost, sawdust, wood chips, shavings and animal manures. To achieve optimum advantage from the organic mulch, the mulch should be applied immediately after germination of crop or transplanting of vegetable seedling. Organic mulch are efficient in reduction of nitrates leaching, improve soil physical properties, prevent erosion, supply organic matter, regulate temperature and water retention, improve nitrogen balance, take part in nutrient cycle as well as increase the biological activity (Hooks and Johnson, 2003; Muhammad *et al*., 2009; Sarolia and Bhardwaj, 2012).

### 2.2.3 Inorganic mulch

Inorganic mulch includes plastic mulch and accounts for the greatest volume of mulch used in commercial crop production. The plastic materials used as mulch are poly vinyl chloride or polyethylene films. Owing to its greater permeability to long wave radiation it can increase temperature around the plants during night in winter. Hence, polyethylene film mulch is preferred as mulching material for production of horticultural crops (Bhardwaj *et al*., 2011). Nowadays, application of black plastic mulch film is becoming popular and very good results have been achieved particularly in arid and semi-arid regions (Bhardwaj *et al*., 2011). Black polyethylene mulches are used for weed control in a range of crops under the organic system of crop production.

Conserve soil moisture: The conservation of soil moisture through mulching due to modification of favorable micro-climatic conditions in soil. When soil surface is covered with organic mulch it helps to prevent weed growth, reduce evaporation and increase infiltration of rain water during growing season. In addition plastic mulch helps in shedding excessive water away from the crop root zone during periods of excessive rain fall. This can reduce irrigation frequency and amount of water used; it may help to reduce the incidence of soil moisture related physiological disorders such as blossom end rot in tomato, fruit cracking in lime and pomegranate. Mohapatra *et al*. (1999). Das *et al*. (1990) and Purohit *et al*. (1990) observed that use of polyethylene mulch in the field, increased the soil temperature especially in early spring, reduced weed problems, and increased moisture conservation, reduction in certain insect pest population, higher crop yield and more efficient use of soil nutrients. Crop residues or mulch on the soil surface act as shade; serve as a vapour barrier against moisture losses from the soil, causing slow surface runoff and

conserves sufficient water in the soil for better development of crops (Rathore *et al*., 1998).

Thakur *et al*. (2000) observed that different mulching materials such as grass, lantana leaves and plastic, helped bell pepper (C. annuum cv. California Wonder) to perform better at water deficits from 25 to 75 per cent and plastic mulch had highest water use efficiency. Hatfield *et al*. (2001) reported a 34-50 per cent reduction in soil water evaporation as a result of crop residue mulching. Mulch slows down evaporation and reduces the irrigation requirement (Anonymous, 2003). Chawla (2006), Khurshid *et al*. (2006), Muhammad *et al*. (2009) stated that mulching improves the ecological environment of the soil and it avoids decrease in soil water levels. Reduced infiltration rate: The presence of crop residue mulch at the soil-atmosphere interface has a direct influence on infiltration of rainwater and evaporation. Mulch cover reduces surface runoff and holds rainwater at the soil surface thereby giving it more time to infiltrate into the soil Abu-Awwad (1999). Khurshid *et al*. (2006) showed that covering of soil surface with reduced the amount of irrigation water required by the pepper and the onion crop by about 14 to 29 and 70 per cent respectively.

## 2.3 Irrigation Water Requirement of Cucumber

Precipitation and in particular its effective portion, provides part of the water crops needed to satisfy their transpiration requirements. The soil, acting as a buffer, stores part of the precipitation water and returns it to the crops in times of deficit. In humid climates, this mechanism is sufficient to ensure satisfactory growth in rain fed agriculture. In arid climates or during extended dry seasons, irrigation is necessary to compensate for the evapotranspiration (crop transpiration and soil evaporation) deficit due to insufficient or erratic precipitation. Irrigation water requirement is defined as the volume of water needed to compensate for the deficit between potential

evapotranspiration on the one side and effective precipitation over the crop growing period and change in soil moisture content on the other side. It varies considerably with climatic conditions, seasons, crops and soil types. For a given month, the crop water balance can be expressed as follows, (Micheal, 1978).

IR = CWR – (ER + S)……..……2.6

Where:

IR = irrigation requirement of the crop, cm

CWR = crop water requirement, cm

ER = effective rainfall, cm

S = soil profile contribution, cm

ER and S are considered to be 0, when there is no precipitation and the water table far below the root zone depth.

## 2.4 Water Use Efficiency of Cucumber

The water use efficiency is described on various scales from leaf of a plant to farm level (Chaves *et.al,* 2002). Viets (1962) presented water use efficiency as the mass ratio of crop yield to water use. WUE is the percentage of water supplied to the plant that is effectively taken up by the plant, i.e., that was not lost to drainage, bare soil evaporation or interception.WUE can be define as biomass produce per unit area per unit water evaportranspired. The biomass is usually determined as dry weight rather than as fresh weight, therefore several methods are commonly used to determine water use efficiency (Fran *et.al*., 1987).Water use efficiency is mainly relaying on the economic yield of the crop rather than water use (Singh *et. al*., 2012). Michael (1978) stated that the term "water use" may either be field water use or actual crop

evaportranspiration, hence differentiating water use efficiency from crop water use efficiency. Burman *et.al*. (1980) gave a more precise definition of WUE as a measure of the increase in the production of the marketable crop component relative to the increase in the water consumed when irrigated over the simultaneous consumption under non- irrigated condition, that is:

$$WUE = \frac{Vi - Vx}{ETi - ETx} \quad \text{.....2.7}$$

Where:

Vi = mass of marketable crop produced with irrigation, t/ha

Vx = mass of marketable crop that could be produced simultaneously without irrigation, t/ha

ETi = amount of water used in ET by the irrigated crop

ETx = amount of water that could be used in ET by the same crop if not irrigated.

Also Micheal (1978) presented two ways of defining water use efficiency: as the crop water use efficiency (CWUE) or as irrigation water use efficiency (IWUE). The CWUE is express as:

$$CWUE = \frac{Y}{ET} \quad \text{.....2.8}$$

Where:

Y = crop Yield, which may be define in terms of the dry matter production or marketable product (Shmueli, 1973; Micheal, 1978).

ET m = amount of water used in evaportranspiration.

While the irrigation water use efficiency is given as

$$IWUE = \frac{Y}{Qf} \quad \text{.....2.9}$$

Where:

Qf = total amount of water used in the field (Micheal, 1978). Under full irrigation and without ground water contribution, Of = Qa which is the amount of water applied to the field.

## 2.5 Irrigation Scheduling

Irrigation scheduling means when to irrigate and how much water to apply. The objective of irrigation scheduling is to maximize yield, irrigation efficiency and crop quality by applying exact amount of water by the crop or to replenish the soil moisture to a desired level. Some indices have been used by irrigators to determine the need of irrigation by crop. These indicators include plant leaf appearance, soil moisture status, soil – water potential, leaf water potential and leaf temperature. Strategies adopted by irrigators are some of the several factors influencing irrigation scheduling. Possible irrigation strategies adopted by farmers include maximizing yield by per unit of land, maximization of water energy and profit. These strategies are affected by the existing land, water and labor resources condition.

## 2.6 Crop Yield and Water Use

The relationship between crop yield and water use is unique; when climatic and agronomic conditions are adequate, crop yield completely depends on the amount of water available for use by the crops. According to Doorenbos and Kassam (1979), when economic conditions do not restrict crop production and in a constraint –free condition, crop yield is at maximum when full water requirements are met. When water supply does not meet crop water requirement, actual evapotranspiration (ETa) falls below maximum evapotranspiration (ETm) resulting to evapotranspiration deficit in plant which may develop to a point where crop growth and yield are adversely affected. The effect of the magnitude and the timing of occurrence of water deficit on crop growth and yield is therefore of major importance in the scheduling available but

limited water supply for the growing period of the crop and in determining the priority of water supply amongst different crops during the growing season.

### 2.6.1 Crop coefficient

To account for the effect of crop characteristics on crop water requirements, crop coefficients (Kc) are determined to relate reference crop evaportranspiration (ETo) to actual crop evaportranspiration (ETc). The effect of crop characteristics on the above relationship is associated with the resistance to transpiration, such as closed stomata during the day, waxing leaves, crop height, roughness, reflection and ground cover. According to (Doorenbos and Pruitt, 1984), crop coefficient can be expressed as;

$$Kc = \frac{ETa}{ETo} \quad \ldots\ldots\ldots\ldots \quad 2.10$$

Where: Kc = crop coefficient

ETa = crop evapotranspiration (mm/day)

ETo = Reference cropevapotransiration (mm/day)

It is necessary to collect local data on growing season and rate of irrigation development in order to draw a crop coefficient curve.

## 2.7 Reference Crop Evapotranspiration

Reference crop evaortransiration is normally used to replace potential/maximum evaportranpiration because of the ambiguities involved in the interpretation of the later. The concept of reference crop evapportranspiration (ETo) is an attempt to characterize the micrometreological environment of a field in terms of an evaporative demand independently of crop type. Burman *et al*. (1983) define reference evaportranspiration as the maximum rate at which water is fully available, would be removed from the earth's surface, and transpired by plant.

### 2.7.1 Crop evapotranspiration

This refer to the rate of evaportranspiration of a disease-free crop growing in a large field (over one ha) under optimal soil condition; including sufficient water and fertilizer, and achieving full production potential of that crop under the giving growing environment (Doorenbos and Pruitt, 1977). If the standard conditions are not satisfied, then the rate of water loss from the cropped land through ET is termed actual crop evaportranspiration. Actual crop evaportranspiration (ETa) is therefore, the rate of evaportranspiration as affected by the level of available soil water, salinity, field size and /or other factors (Doorenbos and Pruitt, 1977).

(Rijov et, al., 1973) report that Eta is obtained from the change in soil water content in successive soil sampling intervals as follows:

$$ETa = \sum_{i=1}^{n} \frac{M1i - M2i}{t} . Di \quad \text{.....2.11}$$

Where:

ETa = actual crop evaportranspiration from the root zone in mm, for a sampling period within one irrigation circle.

$M_{1i}$ = moisture percentage basis at the first sampling in the i-th layer.

$M_{2i}$ = moisture percentage basis at the second sampling in the i-th layer.

$D_i$ = depth of soil in mm of the i-th layer

t = time for water application

## 2.8 Soil Moisture Content

Soil water is important in agriculture because of its strong influence on plant growth and crop production. Most studies related to the soil – plant – atmosphere continuum are invariably pivoted about accurate measurement of soil moisture. Typical studies requiring the determination of soil moisture content include: estimation of the total available water capacity, measurement of actual crop evaportranspiration using the soil moisture depletion method, determination of water application efficiencies, among others.

Mazumder (1983) defined soil moisture content as the percentage of moisture present per unit dry weight of soil. The gravimetric method is apparently the most prevalent technique in vogue for determination of soil moisture content. It involves weighing a sample of moist soil, drying it to constant weight at a temperature of 105 to 110$^{o}$C and reweighing to determine the amount of water lost upon drying. Soil moisture content is then calculated as follows (Skaggs *et al*., 1980):

$$\theta_{dw} = \frac{Wt_{ms} - Wt_{ds}}{Wt_{ds}} \times 100\% \quad \text{.....2.12}$$

where:

$\theta_{dw}$ = soil moisture content, % dry weight basis

$Wt_{ms}$ = weight of moist soil,

$Wt_{ds}$ = weight of dry soil, g

## 2.9 Characteristics of Experimental Crop

The cucumber most likely originated in India (south foot of the Himalayas), or possibly Burma, where the plant is extremely variable both vegetative and in fruit

characters. Cucumber demands high temperatures and soil moisture for satisfactory yield, and under unfavorable climatic conditions, several problems may occur, such as the reduction of female flowers (Yaghi *et al*., 2013). The cucumber responds like a semitropical plant. It grows best under conditions of high temperature, humidity, and light intensity and with an uninterrupted supply of water and nutrients (Dipa, 2006). Under favorable and stable environmental and nutritional conditions and when pests are under control, the plants grow rapidly and produce heavily. (Dipa, 2006) Under optimal conditions, more fruit may initially develop from the axils of 4 each leaf than can later be supported to full size, so fruit may need thinning. Plants allowed to bear too much fruit become exhausted, abort fruit, and fluctuate widely in productivity over time. Excessive plant vigor is indicated by: rapid growth, thick and brittle stems large leaves, long tendrils, deep green foliage, profusion of fruit, and large, deep yellow flowers. On the other hand, cucumbers are very sensitive to unfavorable conditions, and the slightest stress affects their growth and productivity (Ertek,*et al.*, 2006).

# CHAPTER THREE

# 3.0 MATERIALS AND METHODS

## 3.1 Description of the Study Area

The experiment was conducted during the dry season of 2016 at the Irrigation Research Farm of Institute for Agricultural Research (I. A. R.), Samaru-Zaria, Nigeria. The farm is located at Latitude 11°11'N, Longitude 7°38'E and altitude 686 m above sea level and described as a semi-arid region. The area has three seasons in a year; a hot dry season, which spans from March to May; a warm rainy season from June to early October, and the cool dry (Harmattan) season which spans from November to February. The average relative humidity of the area is 36.0 % during the dry season and 78.5 % during the wet season, and the average minimum and maximum temperatures are 15.6 and 38.5°C, respectively (Table 3.1).

## 3.2 Treatment and Experimental Design

The two factors investigated in the experiment are deficit irrigation and mulching condition. The treatments consisted of four deficit irrigation levels (100, 75, 50, 25 %) respectively, and three types of mulch materials (No Mulch, Black Polythene, and Rice Straw Mulch) (Table 3.2). The treatments were laid in a Randomized Complete Block Design (RCBD) in Split Plot arrangement and replicated three times.

## 3.3 Experimental Plot Size

A total of 12 treatments (4x3) replicated three times was used for the experiment. Spit plot Design (SPD) was adopted as the experimental layout replicated three times, where the irrigation was allocated to the main plots and mulching was on the sub-plots. Thus there were a total number of 12 treatments, 3 replications and 36 plots. A plot was 3m x 3m in size (Figure 1).

Table 3.1: Average Daily Weather data for the months during the experiment for the 2016 irrigation season

| **Months** | **Tmax (ºC)** | **Tmin (ºC)** | **RHmax (%)** | **RHmin (%)** | **Windspeed (m/sec)** | **Net Radiation (Kj/m)** | **Sunshine (hr)** | **Precipitation (mm/day)** |
|---|---|---|---|---|---|---|---|---|
| JAN | 28.50 | 13.70 | 20.70 | 11.19 | 10.0 | 17.30 | 8.80 | 0 |
| FEB | 32.70 | 16.60 | 24.60 | 12.30 | 8.0 | 19.70 | 10.0 | 0 |
| MAR | 36.90 | 23.50 | 29.80 | 21.20 | 8.0 | 18.80 | 6.70 | 12.5 |
| APR | 38.50 | 2.20 | 30.50 | 22.80 | 8.0 | 20.00 | 8.70 | 2.20 |

Source: I.A.R. weather Station Ahmadu Bello University, Zaria. 2016.

Table 3.2: Description of experimental Treatments

| Treatment No. | Treatment Combinations | Description of treatment Combination |
|---|---|---|
| 1. | $I_{100}$ NM | 0% moisture depletion, with no mulch |
| 2. | $I_{100}$ BP mulch | 0% moisture depletion, with black polythene mulch |
| 3. | $I_{100}$ RS mulch | 0% moisture depletion, with rice straw mulch |
| 4. | $I_{75}$ NM | 25% moisture depletion, with no mulch |
| 5. | $I_{75}$ BP mulch | 25% moisture depletion, with black polythene mulch |
| 6. | $I_{75}$ RS mulch | 25% moisture depletion, with rice straw mulch |
| 7. | $I_{50}$ NM | 50% moisture depletion, with no mulch |
| 8. | $I_{50}$ BP mulch | 50% moisture depletion, with black polythene mulch |
| 9. | $I_{50}$ RS mulch | 50% moisture depletion, with rice straw mulch |
| 10. | $I_{25}$ NM | 75% moisture depletion, with no mulch |
| 11. | $I_{25}$ BP mulch | 75% moisture depletion, with black polythene mulch |
| 12. | $I_{25}$ RS mulch | 75% moisture depletion, with rice straw mulch |

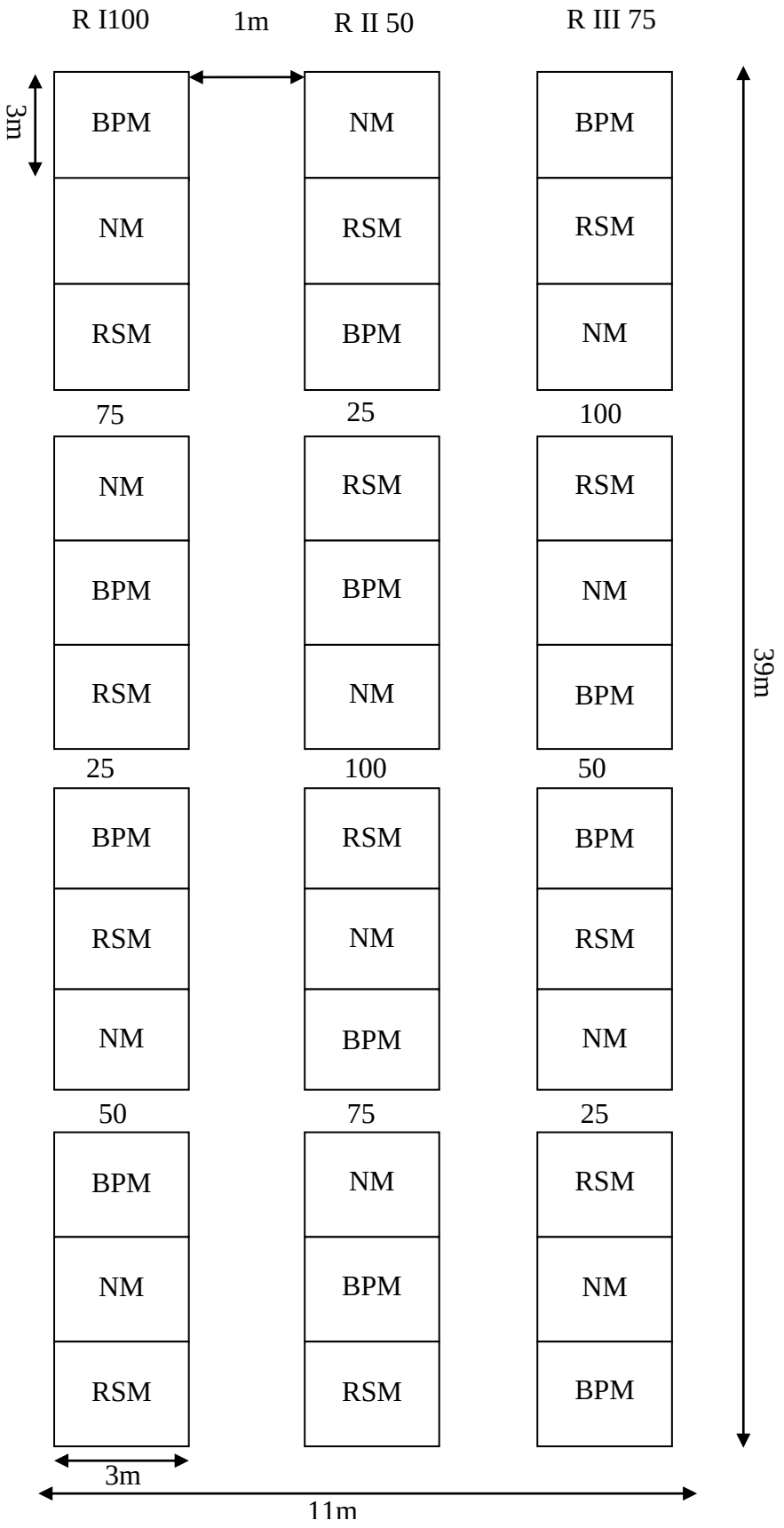



Figure 1: Experimental Field Layout Split Plot Design (SPD)

## 3.4 Water Application

Surface irrigation method was used to convey water through field ditches which ran parallel to the basins. Water was conveyed from the main canal through the lateral ditch by gravity to the field ditches through which it enters the basins. A PVC pipe of 7.5 cm diameter by 50 cm length was used for the conveyance of water into the basins. The pipe was placed at the entrance of each plot to give a free orifice flow. Graduated gauges were placed at the inlet of each basin to measure the water depth; of water flowing through the pipe, and water discharge through the pipe into the basin were calculated using equation 3.4.

The depth of water applied was determined using a stop watch to record the time taken to apply the required depth of water using equation 2.2 and 2.3

A plastic cover cork was used to cut off the flow of water into the basins at the end of the calculated time and to close the inlet.

$Q = C_d A \sqrt{2gh}$ ……3.4

Where: Q = discharge in $m^3$

$C_d$ = coefficient of discharge was taken to be 0.65 as adopted by Halilu (2014)

A = area of the orifice in $m^2 = \frac{\pi d^2}{4}$

h = height of water above the orifice in m

g = acceleration due to gravity in m

## 3.5 Placement of Mulch Materials

At four weeks after planting, when the cucumber crop was fully established, the mulch treatments were imposed. 6kg/$m^2$ of rice straw was applied uniformly on each basin according to treatment description. The black polythene mulch of low density

was cut into 3.5 by 3.5m and spread on the 3mx3m plot respectively. A small hole was made on the polythene for each Cucumber crop stand.

### 3.6 Soil Data Analysis

For the purpose of textural classification of the root zone profile of the experimental site, soil particle analysis was carried out prior to planting on soil samples at some incremental depths of 0 -15 cm, 15 -30 cm and 30 -45 cm. Soil hydraulic properties such as water holding capacity, the moisture content at field capacity and at wilting point conditions were determined in the soil science laboratory of Ahmadu Bello University, Zaria. Similarly soil physical properties like bulk density, and pH, were also determined (Table 3.3).

### 3.7 Cultural Practice

The cucumber seeds were planted at 0.5 m by 0.75 m inter-row and intra-row spacing respectively in well leveled basins.

The cucumber seed were planted three seed per hole at a depth of 3cm and thinning was done two weeks after planting (WAP). Irrigation was done before planting to facilitate soil leveling, a second irrigation just after sowing, and thereafter every week until four weeks after sowing then the irrigation treatments were imposed. Fertilizer was applied at the rate of 100 Kg/ha of N, 60 Kg/ha of P, and 60 Kg/ha of K, half at planting and the second half at 4 WAP as recommended by the FAO (2002). Pesticides were applied using laraforce® with active ingredient: lambda-cyhilothrine 2.5% EC at the rate of 0.5 – 0.8l/ha. Weeding was done manually at three weeks after sawing and thereafter two weeks intervals throughout the growing season. Harvesting was done manually by hand picking after the crop attained maturity stage at 60 days after sawing.

Table 3.3 Physical Properties of the Soil at the Experimental site.

| Depth (cm) | Moisture @ Fc % 33Kpa | Moisture @ Pwp % 1500Kpa | Bulk Density ($g/cm^3$) | | | | |
|---|---|---|---|---|---|---|---|
| | | | | Clay | Silt | Sand | Textural Class |
| 0 – 15 | 12.1 | 33.5 | 11.84 | 330 | 441 | 3 30 | Clay loam |
| 15 – 30 | 15.9 | 44.5 | 11.50 | 440 | 335 | 2 26 | Clay loam |
| 30 – 45 | 18.6 | 55.1 | 11.56 | 441 | 331 | 2 28 | Clay loam |

### 3.7.1 Measurement of soil moisture

The amount of water depleted from a soil was determined with the use of theta probe instrument, measurement of soil moisture at different depth in the soil profile was carried out, and water extracted per day from the soil was computed for each period. The readings were taken in-situ by inserting the instrument into the desired depth of soil through access tubes which were already installed in each hole and recorded.

### 3.7.2 Determination of actual crop evapotranspiration (ETa)

The actual crop evapotranspiration was determined from measured soil moisture content data using theta probe instrument. The level of soil moisture depletion in volumetric basis at three various root zone depths of 15, 30, 45 cm, respectively at a number of times throughout the growing period was measured with the use of theta probe.

Since the principle of irrigation is the application of water to the soil at and within the root zone with application rate less than or close to the soil infiltration rate, run off and deep percolation, in this case was assumed to be nil because water was confined within the basin and below field capacity. Thus the actual crop evapotranspiration was determined from equation 2.11 (Michael, 1978).

### 3.7.3 Determination of crop water use and irrigation water use efficiencies

The crop water use efficiency (CWUE) is expressed as the economic yield divided by the seasonal crop water use (seasonal evapotranspiration) Flenet *et al*. 1996. Also Micheal (1978) present two ways of defining water use efficiency: as the crop water use efficiency (CWUE) or as irrigation water use efficiency (IWUE). The CWUE is expressed was determined using equation 2.8

On the other hand the irrigation water use efficiency (IWUE) is expressed as the economic yield divided by the total irrigation water applied (Howell *et al*., 1990, Ibragimov *et al*., 2007). This was determined using equation 2.9 and values were recorded.

### 3.8 Crop Data Yield Parameters and Data Analysis

Crop parameter during harvest such as number of fruits per plant, weight of fruit, size, marketable yield, were collected and analyzed. With appropriate sampling techniques, cucumber plant per plot was marked. The total number, weight and size of fruit per plot were determined at the end of the late season. The average weight and size of fruit per plant, per plot for each treatment were determined.

### 3.9 Yield Response Factor to Water Deficit

The Parameters (Ya, Ym, ETa and ETm), were used in equation 2.1 to determine yield response factor ky, and the values were recorded.

In calculating Ky, the maximum water requirement and maximum yield of cucumber at 0% deficit level was used as ETm and Ym, respectively.

In addition, the crop water use efficiency (CWUE) was determined using equation 2.8 and the values were recorded.

### 3.10 Crop Coefficient

By using the Penman Monteith Equation, crop coefficient was calculated from equation 2.10 by relating the measured crop evapotranspiration (ETa); (Allen *et al*., 1998).

### 3.11 Crop evapotranspiration (ETo)

The reference evapotranspiration was estimated with the use of CROWAT 8.0 software. The weather data for maximum and minimum temperature, sunshine, maximum and minimum Relative Humidity, and wind speed for six months were obtained from the Institute for Agricultural Research (I.A.R.), Ahmadu Bello University, Zaria.

### 3.12 Data Analysis

The collected data was subjected to analysis of variance (ANOVA) and the treatment means were separated using Duncan multiple range test (DMRT) at 5% level of significance.

# CHAPTER FOUR

# 4.0 RESULTS AND DISCUSSION

## 4.1 Cucumber Yield and Yield Parameters

The Results of the twelve treatments on yield of cucumber produced during the 2015/ 2016 dry season are presented in Table 4.1a. Cucumber fruits from each plot were harvested and the weight and size of each fruit were recorded. The fruits sizes were classified as small, medium and large respectively. The lowest yield of 4.33 t/ha was obtained from the plot treated with 75% moisture depletion and no mulch ($I_{25}$ NM), followed by yield of 5.88t/ha obtained in the plot treated with ($I_{50}$ NM), followed by yield of 6.30 t/ha obtained in the plot treated with ($I_{75}$ NM). Yield of 7.31 t/ha was obtained from the plot treated with ($I_{100}$ NM), followed by 8.44 t/ha, 8.40 t/ha, and 8.16 t/ha obtained from the plot ($I_{25}$BPM), ($I_{50}$ BPM) and ($I_{75}$ BPM), respectively. The yield of 9.30 t/ha was obtained from the plot ($I_{100}$ RSM), yield of 10.76 t/ha and 10.01 t/ha were obtained from the plot ($I_{25}$ RSM) and ($I_{50}$ RSM), respectively. Lastly yield of 11.04t/ha obtained from the plot treated with ($I_{100}$ BPM), while the highest value of the cucumber yield 14.60t/ha was obtained from the plot treated with 75% replacement of moisture and rice straw mulch ($I_{75}$ RSM).

The yield obtained per plot ranges from 4.33t/ha to 14.60 t/ha. The 25% moisture depletion with rice mulch record the highest yield of 14.60 t/ha, while the treatment with 75% moisture depletion with no mulch record the least yield of 4.33 t/ha. This indicates that using mulch to conserve water in the soil is beneficial to the crop and also deletion of moisture at 75% has adverse effect in the yield of the crop, because Cucumber is a water loving crop. Similarly, it was observed that the 0% moisture depletion did not produce the highest yield.

Table 4.1a Total Yield and number of cucumber fruit obtained in 2016 dry season.

| Treatments | Total yield(t/ha) | Number of fruits/ha |
|---|---|---|
| $I_{100}M_{RS}$ | 9.03 | 39259 |
| $I_{100}M_{BP}$ | 11.04 | 37037 |
| $I_{100}M_{NO}$ | 7.31 | 26666 |
| $I_{75}M_{RS}$ | 14.60 | 44074 |
| $I_{75}M_{BP}$ | 8.44 | 25925 |
| $I_{75}M_{NO}$ | 6.30 | 18889 |
| $I_{50}M_{RS}$ | 10.01 | 33333 |
| $I_{50}M_{BP}$ | 8.16 | 28518 |
| $I_{50}M_{NO}$ | 5.88 | 15185 |
| $I_{25}M_{RS}$ | 10.76 | 29629 |
| $I_{25}M_{BP}$ | 8.40 | 27777 |
| $I_{25}M_{NO}$ | 4.33 | 19629 |

This might be as a result of high moisture content in the soil that causes excessive humidity and lack of aeration in the root zone of the crop. The highest yield of 14.60 t/ha was slightly higher than the yield of 14.41 t/ha obtained under irrigation with the same variety of cucumber by James, (2014). Similarly the yield obtained from this work was slightly higher than the yield 14.05 t/ha obtained by Ibrahim *et al* (2001), under irrigation.

Table 4.1$_b$ presents the amount of water applied and water use on of cucumber fruit, the treatment with no mulch at 100% moisture depletion replacement consume the highest water applied and water use with the value 236.2 mm and 281.5 mm, respectively. While the least amount of water applied was in the treatment 75% moisture depletion replacement with black polythene with the value 147.2 mm, while the least water use was obtained from the treatment 25% moisture deletion replacement with the value 49.3 mm.

Table 4.1$_b$ Water Use and Water applied for cucumber crop in 2016 dry season.

| Treatments | Water Use (mm) | Water applied (mm) |
|---|---|---|
| $I_{100}M_{NO}$ | 236.2 | 281.5 |
| $I_{100}M_{RS}$ | 210.0 | 214.1 |
| $I_{100}M_{BP}$ | 160.6 | 278.2 |
| $I_{75}M_{NO}$ | 172.5 | 181.7 |
| $I_{75}M_{RS}$ | 127.6 | 162.5 |
| $I_{75}M_{BP}$ | 120.3 | 147.2 |
| $I_{50}M_{NO}$ | 122.5 | 250.6 |
| $I_{50}M_{RS}$ | 88.9 | 154.2 |
| $I_{50}M_{BP}$ | 100.3 | 155.7 |
| $I_{25}M_{NO}$ | 50.6 | 261 |
| $I_{25}M_{RS}$ | 49.3 | 185.5 |
| $I_{25}M_{BP}$ | 48.6 | 104.1 |

These trends of variation in the water applied and water use from one treatment to another may be due to the fact that mulch conserves water in the soil for the crop use.

Table 4.2 presents the effect of irrigation and mulch on the fruit yield and number of fruit of cucumber. Mean fruit yield and number of fruits among irrigation levels were not significant (P>0.05). The treatment with rice straw much produced significantly higher mean fruit yield of 5.964 t/ha compare to black polythene and No mulch which produced 4.510 t/ha and 2.929 t/ha, respectively. Similarly, black polythene produced significantly higher mean fruit yield than No mulch condition (P<0.05). This may be due to the mulch material used in the experiment that conserves water in the soil and reduce evaporation. Mean number of fruits among rice straw and black polythene was statistically similar with value of 37500 number/ha and 29815 number/ha, respectively, but were both significantly higher compare to No mulch condition with the value 20093 number/ha. The interaction between irrigation levels and mulch types were not significant for both mean fruit yield and number of fruits, this may be attributed to the conservation of moisture by both the rice straw and black polythene mulching material.

Table 4.2: Effect of Irrigation and Mulch on yield and number of fruit of cucumber

| Treatment | Fruit Yield ($t\ ha^{-1}$) | Number of fruit (Number/ha) |
|---|---|---|
| Irrigation (%) I | | |
| 100 | 5.921[a] | 34321[a] |
| 75 | 5.530[a] | 29877[b] |
| 50 | 3.691[ab] | 27679[b] |
| 25 | 2.730[b] | 20667[b] |
| SE± | 0.7191 | 0.279 |
| Mulch Type (M) | | |
| Rice Straw | 5.964[a] | 37500[a] |
| Black Polythene | 4.510[ab] | 29815[a] |
| No mulch | 2.929[b] | 20093[b] |
| SE± | 0.622 | 0.318 |
| Interaction | | |
| I x M | NS | NS |
| SE± | 2.03 | 5638 |

Means followed by the same letter along a column are not statistically different using Duncan's Multiple Range Test at 5% probability.

SE = Standard error; NS = not significant.

## 4.2 Effect of Irrigation and Mulch on Irrigation Water depth

Table 4.3 presents the effect of irrigation level and mulch types on irrigation water use by the crops. From the result it is observed that the irrigation water depth and the seasonal water use decreased with increase in percentage irrigation deficit. This pattern of decrease in water use as a result of deficit was expected because deficit

irrigation reduces the quantity of water that is available in the root zone for the crop to use. The highest irrigation water depth was found to be 223.3 mm, under irrigation treatment at 100% ($I_{100}$), which was significantly higher than those of other irrigation deficits. This was followed by 213.7 mm under irrigation treatment at 75% ($I_{75}$). Then, followed by 186.9 mm under irrigation treatment at 50% ($I_{50}$) and the least irrigation water depth was found to be 183.5 mm under irrigation treatment at 25% ($I_{25}$). Also, there was a significant difference among irrigation levels in respect of cucumber seasonal water use. Irrigation treatment at 100% moisture replacement $I_{100}$ had the highest seasonal water use which was significantly higher than other irrigation levels and $I_{25}$ had the least.

Irrigation water depth and seasonal water use in No mulch condition was significantly higher than those basins mulched with rice straw and black polythene respectively. Rice straw mulch also had significantly higher irrigation water depth than Black polythene. Generally, irrigation water depth and seasonal water were found to be decreasing with increase in % of moisture depletion from 100% to 25%. However, with the use of different mulch materials, the irrigation water depth and seasonal water use recorded the highest values at NM with 267.8 mm and 159.2 mm respectively, followed by RSM which recorded 170 mm and 119 mm respectively and the least were recorded at BPM with 167.8 mm 107.5 mm respectively.

Table 4.3: Effect of irrigation and mulch on irrigation water depth and seasonal water use of Cucumber

| Treatment | Irrigation water depth (mm) | Seasonal water use (mm) |
|---|---|---|
| Irrigation (I) | | |
| $I_{100}$ | 223.3[a] | 218.9[a] |
| $I_{75}$ | 213.7[b] | 141.8[b] |
| $I_{50}$ | 186.8[c] | 103.9[c] |
| $I_{25}$ | 183.5[d] | 49.5[d] |
| SE± | 0.21 | 0.30 |
| Mulch Type (M) | | |
| No mulch | 267.8[a] | 159.2[a] |
| Rice Straw | 170.0[b] | 119.0[b] |
| Black Polythene | 167.8[c] | 107.5[c] |
| SE± | 0.05 | 0.26 |
| Interaction | | |
| I*M | ** | ** |

Means followed by the same letter along a column are not significantly different using Duncan's Multiple Range Test at 5% probability

From the result, it was observed that mulching treatment with either rice straw and black polythene recorded lower value compared to no mulch which recorded higher value. Therefore, from the result obtained it can be concluded that mulching help to conserve water for crop use. The interaction between deficit irrigation and mulch treatment material in irrigation water use and seasonal water use of irrigated Cucumber was found to be highly significant.

The interaction of irrigation and mulch on irrigation water depth is presented in Table 4.4 when irrigation was at $I_{100}$, $I_{75}$ and $I_{25}$ no mulch recorded significantly higher irrigation water depth followed by rice straw mulch then black polythene mulch. However, when irrigation was at $I_{50}$, no mulch recorded a significantly higher irrigation water depth but it was followed by black polythene and then rice straw mulch. In general, the highest irrigation water depth was recorded at the treatment with no mulch. This shows that mulch help in conserving moisture in the soil.

The study reveals that deficit irrigation affects the irrigation water depth irrespective of the mulching material used. Generally, the highest irrigation water depth is at irrigation with no mulch and at 100% fully irrigation, while the least irrigation water depth is at irrigation with rice straw mulch and at 25% moisture deletion replacement.

Table 4.4: Interaction of irrigation and mulch on irrigation water depth

| | Irrigation | | | |
|---|---|---|---|---|
| Mulch | $I_{100}$ | $I_{75}$ | $I_{50}$ | $I_{25}$ |
| No mulch | $286.2^{a}$ | $281.5^{b}$ | $250.6^{d}$ | $261^{c}$ |
| Rice Straw | $210.0^{f}$ | $162.5^{h}$ | $154.2^{j}$ | $185.5^{g}$ |
| Black Polythene | $214.1^{e}$ | $120.3^{k}$ | $155.7^{i}$ | $104.1^{k}$ |
| SE± | 0.35 | | | |

Means followed by the same letter along a column are not significantly different using Duncan's Multiple Range Test at 5% probability.

Table 4.5 shows the interaction of irrigation and mulch on seasonal water use. The result shows that Irrigation treatments of $I_{25}$, $I_{50}$, $I_{75}$, and $I_{100}$, plots under no mulch condition recorded the highest seasonal water use which was significantly higher than other mulch types. This was followed by black polythene mulch except at $I_{25}$, where rice straw produced significantly higher seasonal water use than black polythene.

Table 4.5: Interaction of irrigation and mulch on seasonal water use

| | Irrigation | | | |
|---|---|---|---|---|
| Mulch | $I_{100}$ | $I_{75}$ | $I_{50}$ | $I_{25}$ |
| No Mulch | $278.2^{a}$ | $177.5^{e}$ | $122.5^{b}$ | $50.6^{j}$ |
| Rice Straw | $177.7^{d}$ | $127.6^{g}$ | $88.9^{i}$ | $49.3k^{g}$ |
| Black Polythene | $197.2^{c}$ | $160.6^{f}$ | $100.3^{h}$ | $48.6^{k}$ |
| SE± | 0.3 | | | |

Means followed by the same letter along a column are not significantly different using Duncan's Multiple Range Test at 5% probability

The study shows that deficit irrigation affects the irrigation water depth and seasonal water use irrespective of the mulch material used. This is due to fact that relative decrease in the yield and growth indices of the crop was observed.

### 4.3 Effect of Irrigation and Mulch on Crop Water Use Efficiency (CWUE) and Irrigation Water Use Efficiency (IWUE).

The effect of irrigation and mulch on crop water use efficiency and irrigation water use efficiency is presented in Table 4.6. The table shows that treatment with 100% had the highest crop water use efficiency and irrigation water use efficiency, 93.7 kg/ha/mm and 90.3 kg/ha/mm, respectively, which were significantly higher compare to other irrigation levels of $I_{75}$, $I_{50}$, and $I_{25}$. This was followed by $I_{75}$, with the value 79.6 kg/ha/mm and 80.8 kg/ha/mm, respectively, which were also significantly higher than both $I_{50}$ and $I_{25}$. Black polythene had the highest crop water use efficiency and irrigation water use efficiency with 93.1 kg/ha/mm and 93.2 kg/ha/mm, respectively, which was significantly higher than rice straw and no mulch. Crop water use efficiency among rice straw mulch, 72.1 kg/ha/mm and no mulch, 71.4 kg/ha/mm were statistically at par. However, Rice straw mulch with 73.3 kg/ha/mm produced significantly higher irrigation water use efficiency than no mulch with 69.5.

Interaction of irrigation levels and mulch type on crop water use efficiency and irrigation water use efficiency was highly significant at 5% probability test.

Table 4.6: Effect of Irrigation and Mulch on Crop Water Use Efficiency and Irrigation Water Use Efficiency of Cucumber

| Treatment | CWUE (kg/ha/mm) | IWUE (kg/ha/mm) |
|---|---|---|
| Irrigation (I) | | |
| $I_{100}$ | 93.7[a] | 90.3[a] |
| $I_{75}$ | 79.6[b] | 80.8[b] |
| $I_{50}$ | 76.8[c] | 78.0[c] |
| $I_{25}$ | 65.3[d] | 65.5[d] |
| SE± | 0.76 | 0.20 |
| Mulch Type (M) | | |
| Black Polythene | 93.1[a] | 93.2[a] |
| Rice Straw | 72.1[b] | 73.3[b] |
| No Mulch | 71.4[b] | 69.5[c] |
| SE± | 0.66 | 0.18 |
| Interaction | | |
| Irrigation*Mulch | ** | ** |

Means followed by the same letter along a column are not significantly different using Duncan's Multiple Range Test at 5% probability

From the result obtained with different mulch materials black polythene holds the highest crop water use efficiency and irrigation water use efficiency. While No mulch treatment holds the least crop water use efficiency and irrigation water use efficiency.

This indicates that combination of irrigation and black polythene mulch gives the highest water use efficiency in the study area. Generally, the water use efficiency increase as deficit irrigation decreases. This result is in line with the earlier report of Alomran and Luki (2012).

Table 4.7 presents the interaction effect of irrigation and mulch on crop water use efficiency. When irrigation was given at $I_{100}$, $I_{75}$ and $I_{25}$, black polythene had significantly higher CWUE than other mulch types but when $I_{50}$ was applied, rice straw mulch was significantly higher than other mulch types.

Table 4.7: Interaction effect of irrigation and mulch on crop water use efficiency

| | Irrigation | | | |
|---|---|---|---|---|
| Mulch | $I_{100}$ | $I_{75}$ | $I_{50}$ | $I_{25}$ |
| BlackPolythene | $127.6^{a}$ | $85.2^{c}$ | $84.8^{c}$ | $75.0^{d}$ |
| RiceStaw | $55.8^{f}$ | $68.9^{e}$ | $99.6^{b}$ | $63.9^{e}$ |
| Nomulch | $97.6^{b}$ | $84.7^{c}$ | $46.0^{g}$ | $57.1^{f}$ |
| SE± | 1.32 | | | |

Means followed by the same letter along a column are not significantly different using Duncan's Multiple Range Test at 5% probability

Table 4.8 shows the interaction effect of irrigation and mulch on irrigation water use efficiency of the area. The irrigation levels of $I_{100}$, $I_{75}$, and $I_{25}$ with black polythene mulch recorded significantly higher IWUE value of 124.1 kg/ha/mm, 86.4 kg/ha/mm, and 76.2 kg/ha/mm, respectively. This was followed by rice straw mulch with value of 57.0 kg/ha/mm, 70.1 kg/ha/mm and 65.2 kg/ha/mm, respectively, then followed by no mulch with 89.7 kg/ha/mm, 85.9 kg/ha/mm 55.0 kg/ha/mm. However, when irrigation was given at $I_{25}$ higher IWUE was obtained with rice straw mulch, followed

by back polythene mulch and then no mulch. Adopting black polythene mulch and no mulch, the highest IWUE was at $I_{100}$ followed by $I_{75}$. $I_{50}$ in black polythene was higher $I_{25}$, but it was the reverse in no mulch. However, with rice straw mulch, the highest IWUE was at $I_{50}$ followed by $I_{75}$ then $I_{25}$, while the least was at $I_{100}$. The results were similar to result obtained by El- Shaikh and T. Fouda (2008). This may be attributed to the mulching material used in the study that conserves water.

Table 4.8: Interaction effect of irrigation and mulch on irrigation water use efficiency

| | Irrigation | | | |
|---|---|---|---|---|
| Mulch | $I_{100}$ | $I_{75}$ | $I_{50}$ | $I_{25}$ |
| BlackPolythene | $124.1^{a}$ | $86.4^{d}$ | $86.0^{d}$ | $76.2^{e}$ |
| RiceStraw | $57.0^{g}$ | $70.1^{d}$ | $100.0^{b}$ | $65.2^{f}$ |
| Nomulch | $89.7^{c}$ | $85.9^{d}$ | $47.3^{i}$ | $55.0^{h}$ |
| SE± | 0.35 | | | |

Means followed by the same letter along a column are not significantly different using Duncan's Multiple Range Test at 5% probability

### 4.4 Yield Response Factor

The yield response factors (Ky) for the RSM, BPM and NM treatments, were 1.012, 1.301 and 0.396 respectively, This were obtained by plotting the data of the relative yields (1-ya/ym) and relative Evaportranspiration (1-Ea/Em) of each treatment.

From the result obtained it shows that the treatment with RSM and NM indicates that when deficit irrigation was applied the crop yield was decreased, and the coefficient of determination of 0.99 and 0.92 were obtained for each relationship for rice straw mulch and black polythene mulch. According to Doorenbos and Kassam (1979), Ky < 1.0 indicates that the decrease in yield is higher with increase in water deficit, while yield decrease is less when Ky>1.0. The results of this study show that without mulch, the yield decreases of the Cucumber crop was greater with increase in

evapotranspiration deficit. It is however noticed that the Ky values of the No Mulch treatment was less than the mulched treatment, which implies that the proportional decrease in yield under the no mulch condition was much higher than the mulched condition. It also suggests that mulching helped to cushion the impact of the deficit irrigation on yield. The Ky values are crop specific and vary over the growing season according to growth stages.

The results presented were in consonance with those of Dean ban *et al.* (2004) in water melon, Ansary and Roy (2005) in water melon, Cenobio *et al.* (2007) and Arancibia and Motsenbocker (2008) in water melon, Siwek and Kunicki (1998), Ibarra–Jimenez *et al*. (2008), Hallidri (2001) in cucumber, Ibarra *et al.* (2001) in muskmelon. The Ky values obtained in this study closely agrees with Doorenbos and Kassam (1979) which gave seasonal Ky value of onion crop as 1.10.

### 4.5 Soil Moisture Depletion Trend

The soil moisture prior and post irrigation at 15 days interval was determined by volumetric method from 0-15, 15-30 and 30-45 cm depth of soil profile for all mulched and un-mulched plots. Soil water content at field capacity was 40.0 percent. Soil moisture was always closer to field capacity throughout the period and the irrigation differed for mulched and non mulched plots depending upon soil moisture depletion. The mean moisture content in rice straw mulched plots observed at 0-15, 15-30 and 30-45 cm depth of soil profile was in the range of 26.2 to 40.2, 30.3 to 43.1 and 32.2 to 48.1 percent, respectively at 100% of irrigation, in black polythen mulched plots it range was 27.3 to 42.0, 30.9 to 42.2, 35.1 to 43.0 cm respectively, in the non mulched plots, it range was 25.9 to 39.3, 28.1 to 35.0 and 30.3 to 37.1. Whereas irrigation at 75% with rice straw mulch record means moisture content range from, 26.0 to 39.1, 31.2 to 37.9 and 38.0 to 45.2, respectively, while black polythen

mulched plots range from 26.1 to 41.1, 34.4 to 46.2 and 3.1 to 47.2, respectively, and for the plots without mulch at the same irrigation application it ranges from 26.4 to 39.4, 32.0 to 43.1 and 30.1 to 44.0, respectively. Thus overall we can see that soil moisture under mulched plots of irrigation were higher than non mulched plots.

Figure 4-15 illustrates the soil moisture depletion trend taken over the course of the 2016 growing season of cucumber crop at different irrigation depths and mulching. On each graph, three reference moisture levels are indicated including field capacity (FC) which was 40 % and permanent wilting point (PWP) which was 26 %, and three different soil profile depths (0-15, 15-30 and 30-45 cm) respectively. By investigating the trend pattern with regards to irrigation depths, it can be seen that the soil moisture content under the treatment irrigated at 100 % was higher than that of 75 %, 50 % and 25 % respectively. It was notice that at 100 % irrigation there was over irrigation almost throughout the season as it slightly exceeds the field capacity especially the treatment with RSM and BPM, and much of deficit was not observed, while the treatment with no mulch maintain the soil moisture content between field capacity and reasonably beyond the wilting point. This could be attributed to the fact that there is insufficient moisture in the soil for crop uptake due to no mulch.

It was also observed that soil moisture used by the crop in 0-15 cm, depth was much higher than that 15- 30 cm and 30-45 cm depths in all cases, respectively. The soil moisture declined progressively with increase in depth. Similar soil moisture depletion trend was reported by Kumar and Sahu (2013).

However, moisture content under no mulch plots suffers more depletion compare to the plots with RSM AND BPM, respectively. Generally, it could be concluded that the soil moisture under mulched plots were higher than no mulch plots. Job *et al*, (2015), reported a similar effect on the moisture depletion trend.

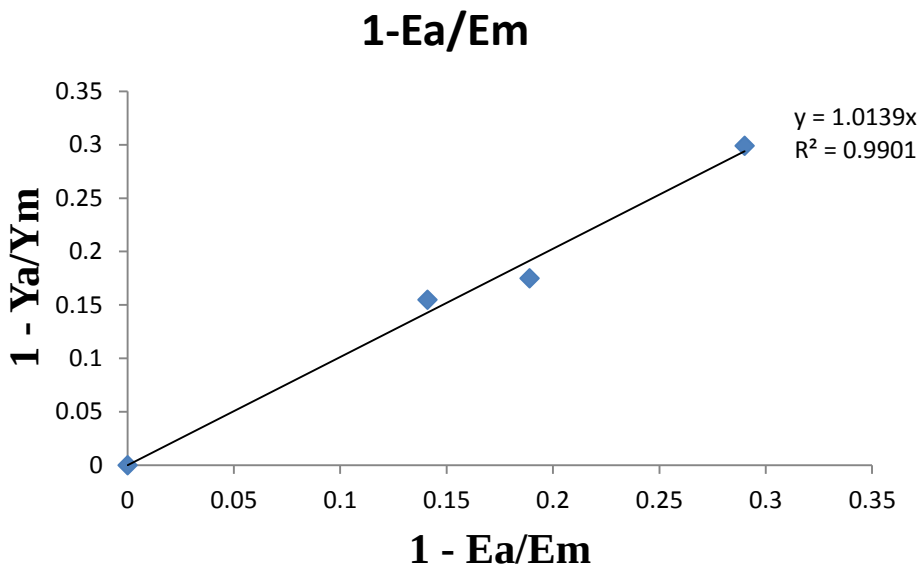



Figure 2: The Rice Mulch treatment yield response factor (Ky)

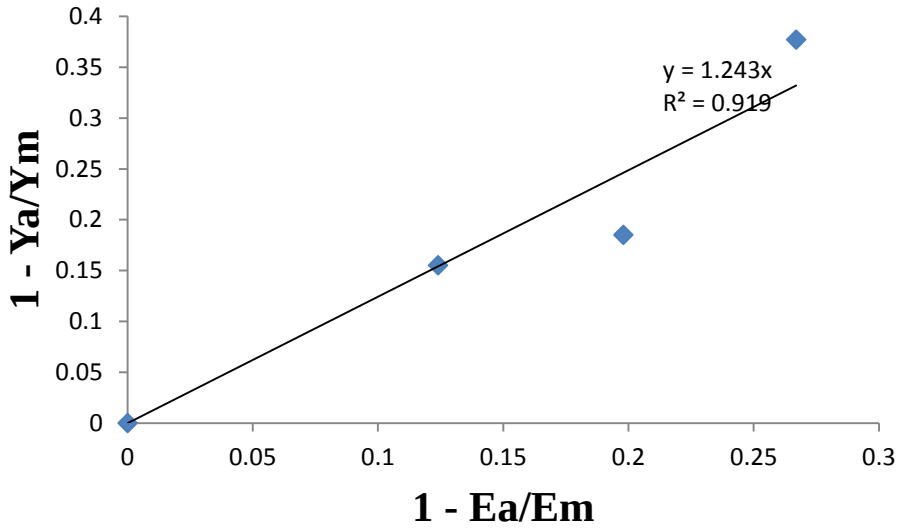



Figure 3: The Black polythene treatment yield response factor (Ky).

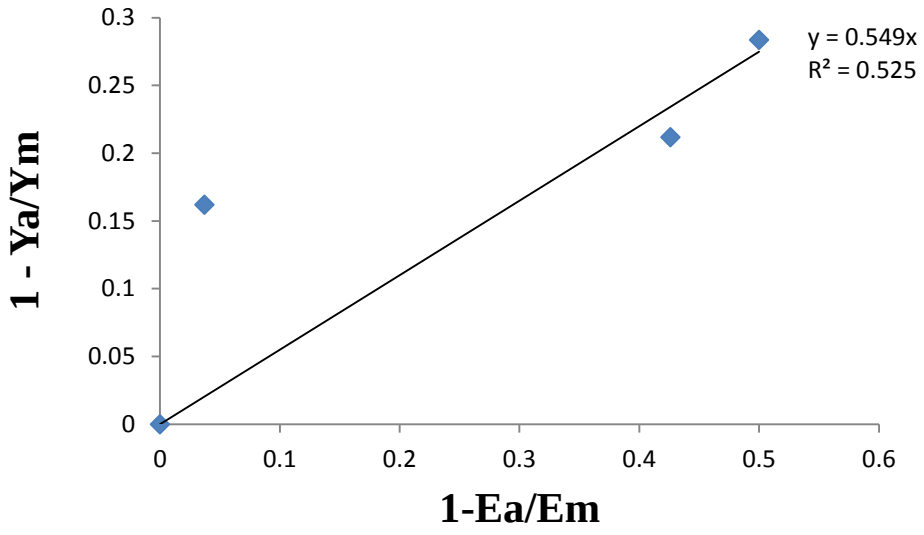



Figure 4: The No mulch treatment yield response factor (Ky).

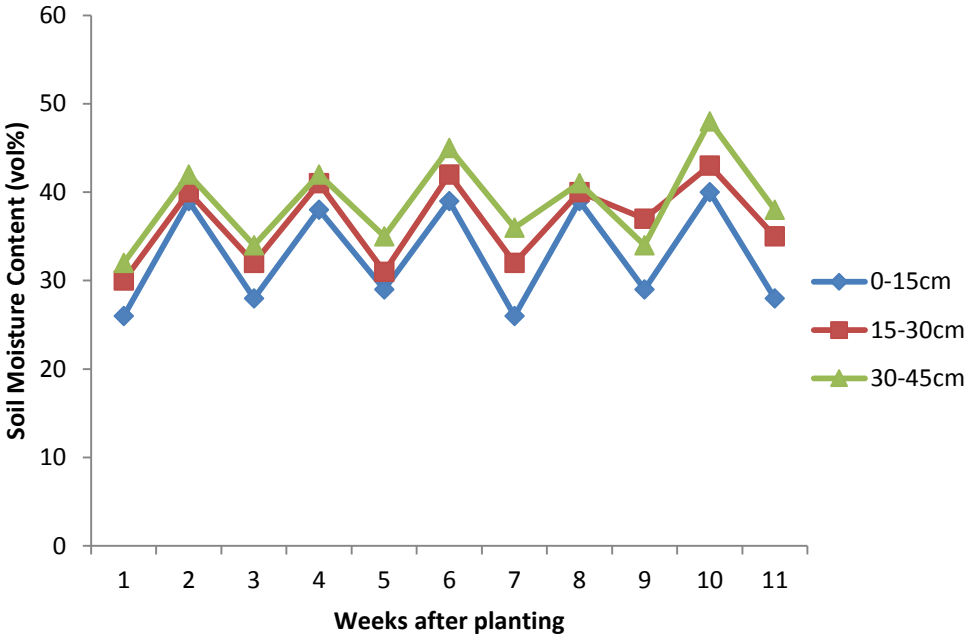



Figure 5: Moisture depletion Trend of cucumber at different soil depth, irrigated at 100% with RSM.

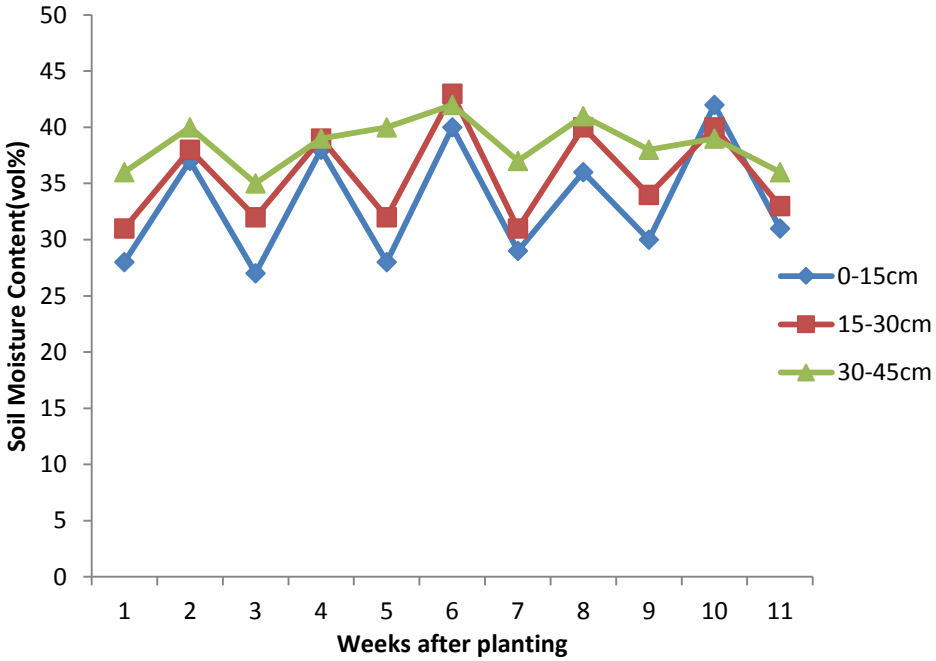



Figure 6: Moisture depletion Trend of cucumber at different soil depth, irrigated at 100% with BPM.

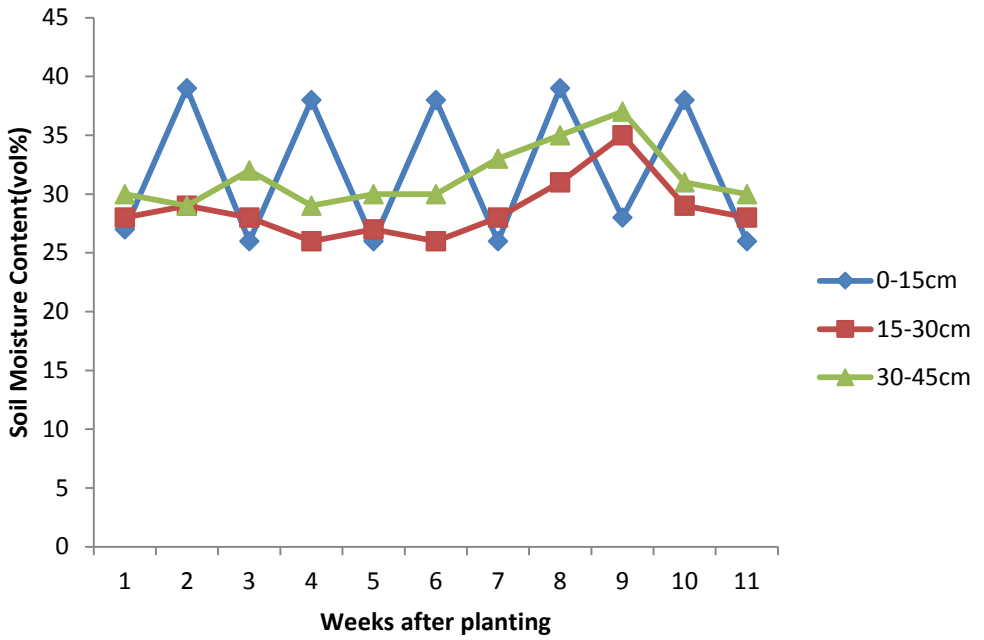



Figure 7: Moisture depletion Trend of cucumber at different soil depth, irrigated at 100% with NM

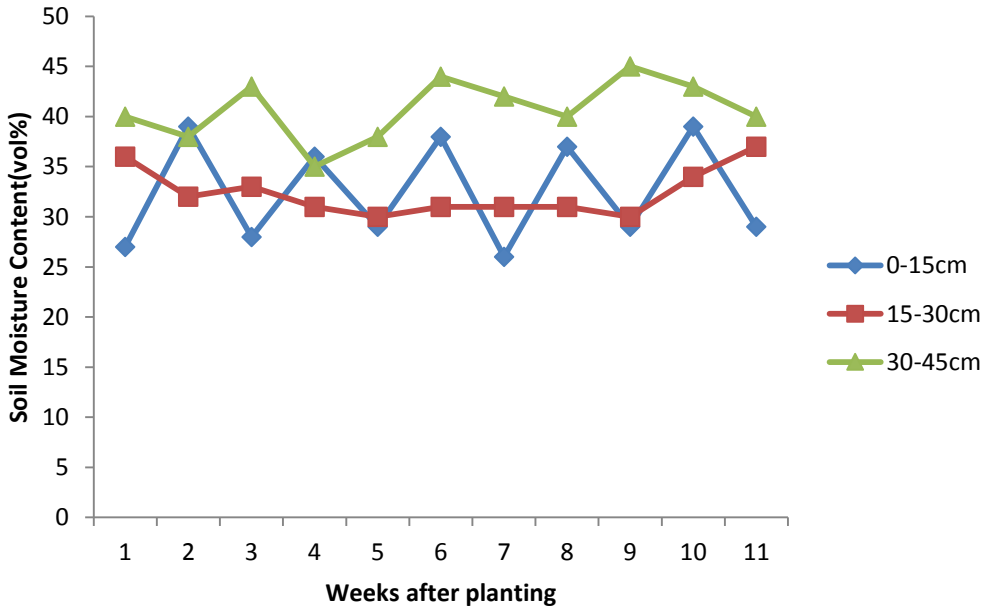



Figure 8: Moisture depletion Trend of cucumber at different soil depth, irrigated at 75% with RSM

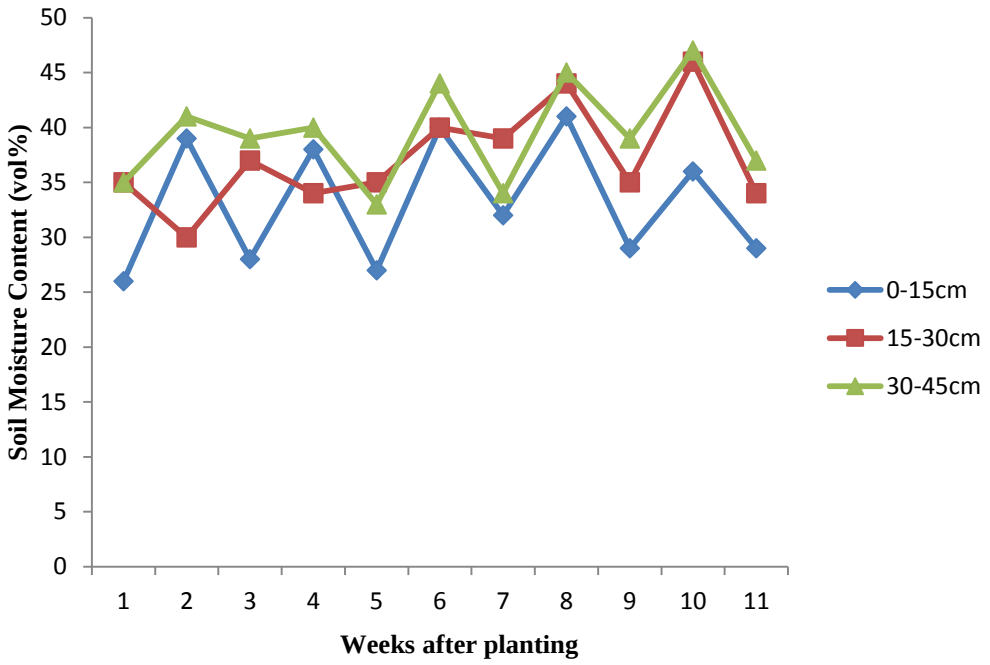



Figure 9: Moisture depletion Trend of cucumber at different soil depth, irrigated at 75% with BPM

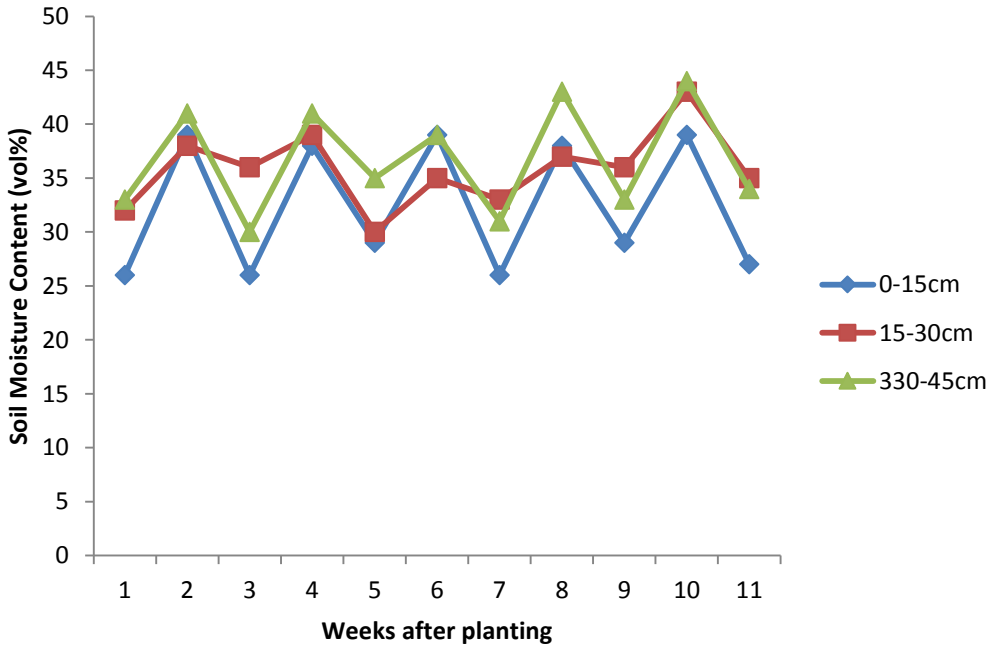



Figure 10: Moisture depletion Trend of cucumber at different soil depth, irrigated at 75% with NM

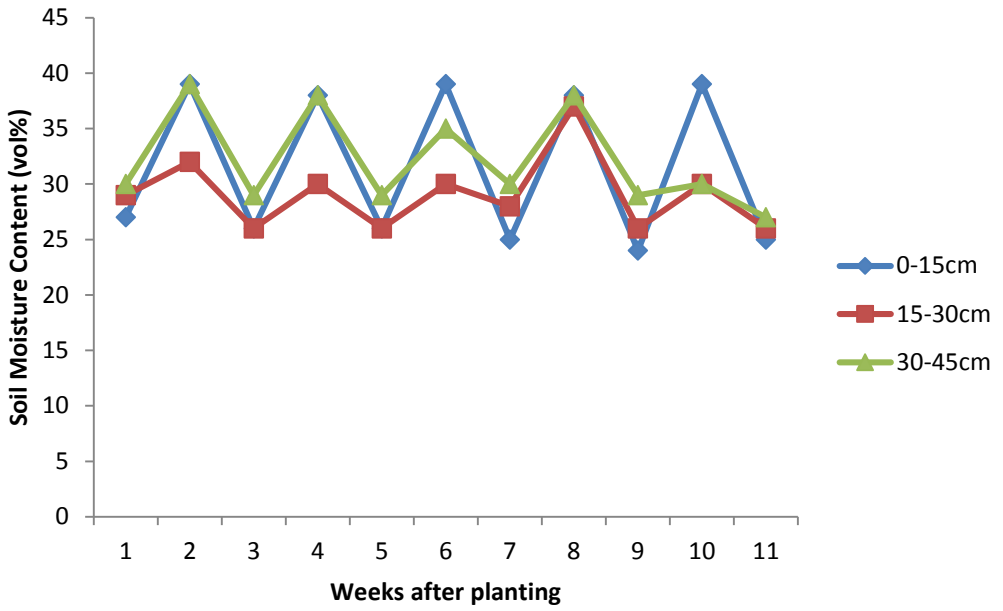



Figure 11: Moisture depletion Trend of cucumber at different soil depth, irrigated at 50% with RSM

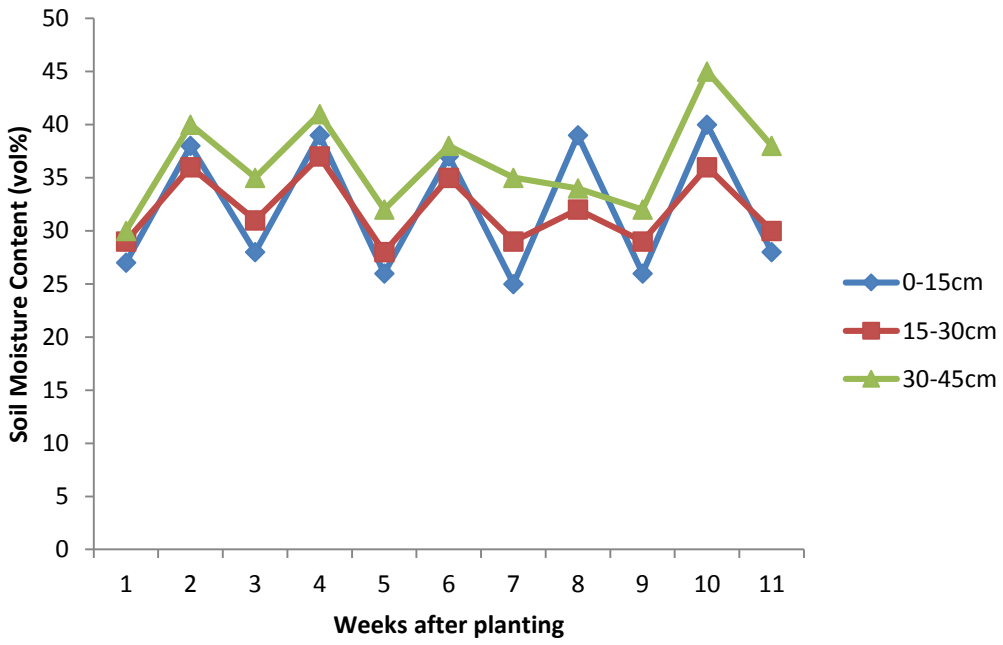



Figure 12: Moisture depletion Trend of cucumber at different soil depth, irrigated at 50% with BPM

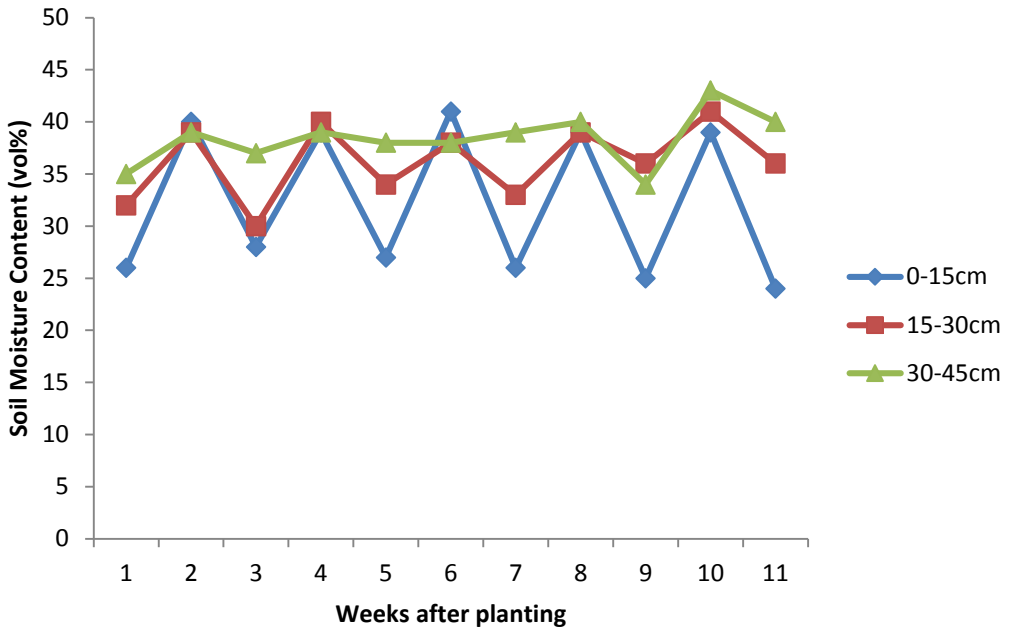



Figure 13: Moisture depletion Trend of cucumber at different soil depth, irrigated at 50% with NM

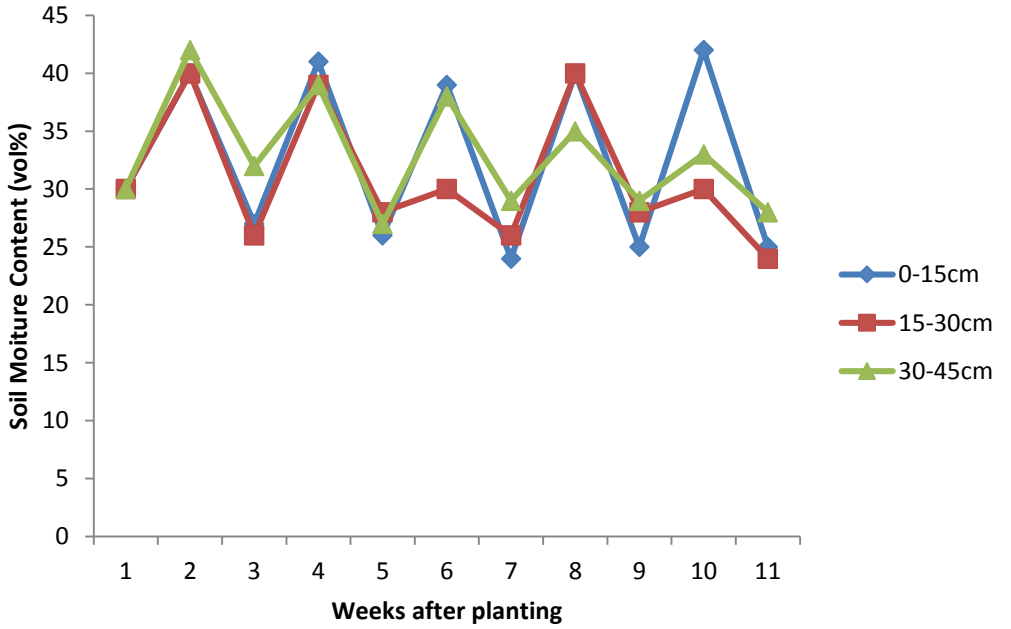



Figure 14: Moisture depletion Trend of cucumber at different soil depth, irrigated at 25% with RSM

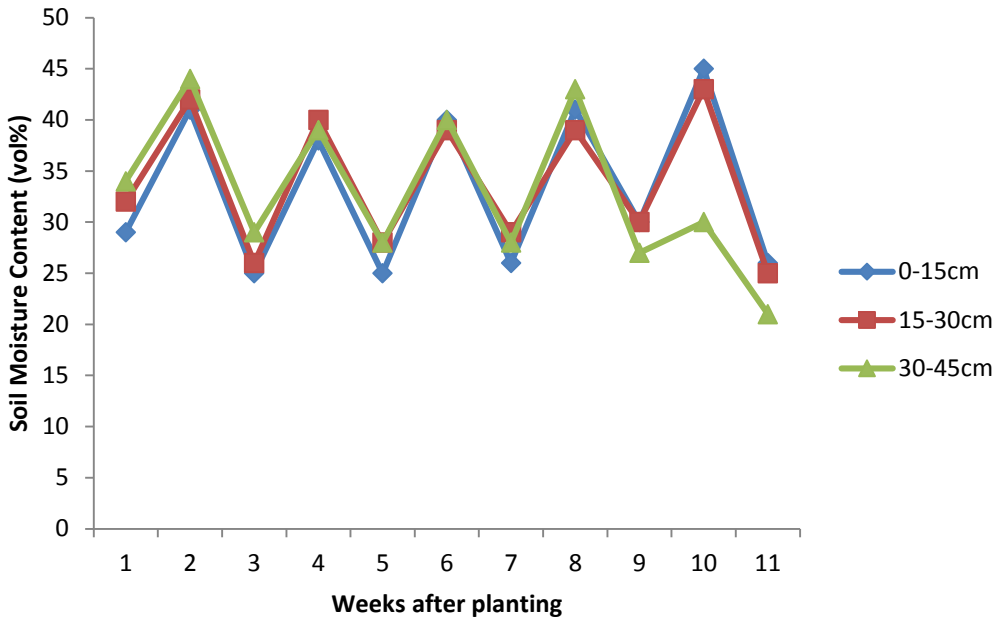



Figure 15: Moisture depletion Trend of cucumber at different soil depth, irrigated at 25% with BPM

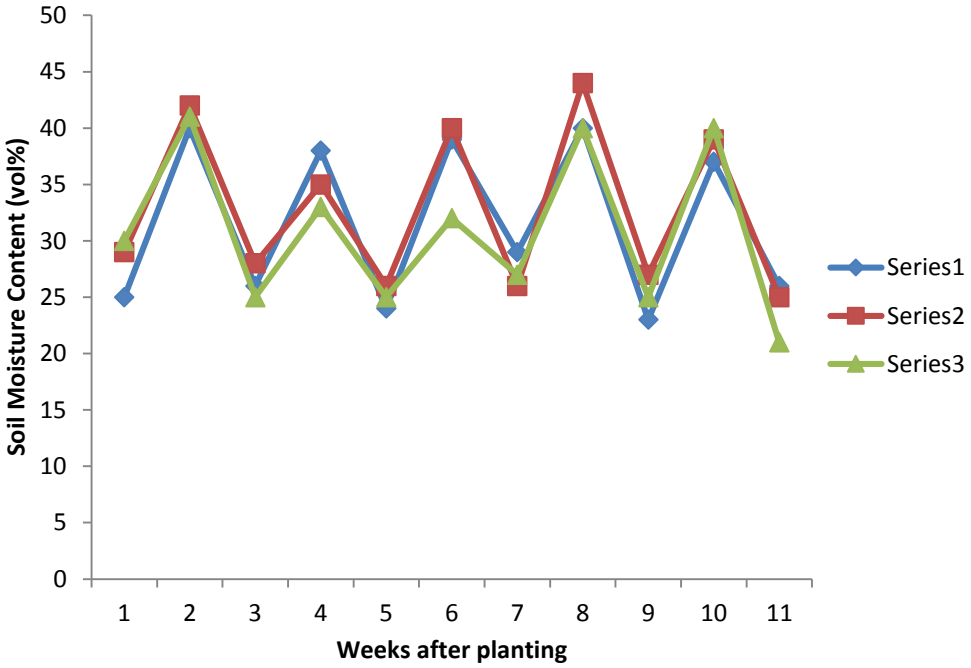



Figure 16: Moisture depletion Trend of cucumber at different soil depth, irrigated at 25% with NM

## 4.6 Crop Coefficient

Table 4.6 shows the values of crop coefficient for cucumber in the experimental area. The table indicates that, the Kc values for RSM ranges from 0.39 – 0.45 for initial growth stage, 0.43 – 0.60 for development growth stage, 0.55 – 0.85 for mid- season growth stage and 0.30 – 0.44 for late season growth. For BPM the value ranges from 0.34 – 0.43 for initial growth stage, 0.49 – 0.66 for development growth stage, 0.0.50 – 0.67 for mid- season growth stage and 0.30 – 0.41 for late season growth stage. For NM the value ranges from 0.39 – 0.45 for initial growth stage, 0.61 – 0.69 for development growth stage, 0.62 – 0.85 for mid- season growth stage and 0.62 – 0.70 for late season growth stage.

The Kc value obtained in this study under BPM at mid- season were lower compare to the values obtained by FAO (2002), because in the cause of the study some of the crops in that particular treatment died due to inadequate amount of water in the root zone of the crop.

FAO (2002) reported Kc values estimated for different growth stages of Cucumber crop as 0.45, 0.70, 0.90, and 0.75 for initial, development, mid-season, and late growth stages, respectively.

Table 4.9: Crop coefficient values for cucumber crop during 2016 dry season.

| Treatments | IS | DS | MS | LS |
|---|---|---|---|---|
| | Kc for Treatment RSM | | | |
| $I_{100}$ RSM | 0.48 | 0.60 | 0.85 | 0.42 |
| | Kc deficit for $M_{RS}$ | | | |
| $I_{75}$ RSM | 0.40 | 0.52 | 0.82 | 0.44 |
| $I_{50}$RSM | 0.45 | 0.51 | 0.55 | 0.30 |
| $I_{25}$RSM | 0.39 | 0.43 | 0.75 | 0.35 |
| | Kc for BPM | Treatment | | |
| $I_{100}$BPM | 0.43 | 0.66 | 0.41 | 0.30 |
| | Kc deficit for $M_{BP}$ | | | |
| $I_{75}$BPM | 0.38 | 0.62 | 0.39 | 0.40 |
| $I_{50}$BM | 0.34 | 0.54 | 0.30 | 0.39 |
| $I_{25}$BPM | 0.35 | 0.49 | 0.32 | 0.39 |
| | Kc for NM | Treatment | | |
| $I_{100}$NM | 0.45 | 0.69 | 0.85 | 0.70 |
| | Kc deficit for $N_M$ | | | |
| $I_{75}$NM | 0.39 | 0.66 | 0.84 | 0.65 |
| $I_{50}$NM | 0.41 | 0.65 | 0.62 | 0.62 |
| $I_{25}$NM | 0.40 | 0.61 | 0.63 | 0.69 |

IS = Initial Stage, DS = Development Stage, MS = Mid-season Stage, LS = Late season Stage

# CHAPTER FIVE

## 5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

### 5.1 Summary

The field experiment was conducted during 2016 dry season at the Institute for Agricultural Research (I.A.R.) farm, Samaru Zaria. Showed the effects of various levels of moisture depletion and different mulching materials on crop yield, seasonal water use, depth of water application and water use efficiency were investigated. Other parameters obtained from the study area were yield response factor and crop coefficient. The experiment was laid out in split plot design (SPD) with 12 treatments; consisting of three mulching materials and four irrigation levels with three randomization.

The cucumber yield from the study was found to range from 4.33t/ha to 14.60 t/ha. The higher yield was obtained when the crop was irrigated at 75% replacement of moisture and with rice straw mulch ($I_{75}$ RSM) with 14.60 t/ha, while the lowest was obtained when the crop was irrigation at 25% moisture replacement and with no mulch ($I_{25}$ NM) with 4.33 t/ha. The maximum marketable yield was at $I_{75}$RSM with 44074 number/ha while the lowest was at $I_{25}$NM with 19629 number/ha. The highest crop water use efficiency (CWUE) was 93.7 kg/ha/mm at 100% level of moisture depletion replacement, while the lowest was 65.3 kg/ha/mm at 25% level of moisture replacement. The irrigation water use efficiency (IWUE) was highest at 100% with the value of 90.3 kg/ha/mm while the lowest was 65.5 kg/ha/mm at 25% level of moisture depletion replacement. The highest seasonal water use was recorded at 100% level of moisture replacement with the value of 670.0 mm while the lowest was 550.6 mm at 25% of moisture replacement. The yield response factor (Ky) obtained was

1.013, for Rice straw mulch treatment; for Black polythene mulch treatment was 1.243 and for No mulch treatment was 0.549. The study showed that crop water use of the cucumber crop decreased with increase in irrigation deficit. The Kc values obtained at initial stages ranges from 0.34 – 0.48, for development stages it was 0.43 – 0.66, for mid- season stages it was 0.30 – 0.85 and for late season it was 0.30 – 0.69.

## 5.2 Conclusion

The following conclusion was drawn from the study:

Seasonal water use and irrigation water applied decrease with increase in percentage of moisture replacement from 100% to 25%. While crop yield decreases with increase in deficit irrigation from 25% to 100%. Mulching also affect the yield of the crop as rice mulch produced higher value compare to black polythene mulch, while the treatment with no mulch recorded the lowest yield as obtained from this research work. Similarly irrigation depth affect the performance of the crop as it yielded lower with lower irrigation water applied and on the other hand it produce higher yield with increase in water application.

The total yields of the cucumber fruit was 104.26 t/ha, the total yields of Cucumber fruits with RSM treatment were 9.03 t/ha, 14.60 t/ha, 10.01 t/ha and 10.76t/ha at 100%, 75%, 50%, and 25% of moisture replacement, respectively. With BPM treatment the total yields were 11.04 t/ha, 8.44 t/ha, 8.16 t/ha, and 8.40 t/ha at 100%, 75%, 50%, and 25%of moisture replacement, respectively. With NM treatment the total yields were 7.31 t/ha, 4.33 t/ha, 5.88 t/ha, 6.30 t/ha at 100%, 75%, 50%, and 25%of moisture replacement, respectively. Therefore the use of rice mulch was the best among other mulch used in this research in terms of higher yield and irrigation water used. The highest crop water use efficiency (CWUE) and irrigation water use

efficiency (IWUE) were 93.7 kg/ha/mm and 90.3 kg/ha/mm at 100% level of moisture depletion replacement and the least was 65.3 kg/ha/mm and 65.5 kg/ha/mm at 25% level of moisture replacement.

The ky values were determine to be 1.013 for rice straw mulch; 1.243 for black polythene and 0.549 for No mulch treatments respectively.

The Kc values ranges from 0.35 – 0.48 for initial stage, 0.43 – 0.66 for development stage, 0.30 – 0.85 for mid – season and 0.30 – 0.69 for late season stage for cucumber in the study area.

## 5.3 Recommendations

The following recommendation were drawn from this study

1. A similar study on similar crop under similar condition in different environment could be conducted in order to obtain adequate information on the crop.
2. In this research deficit irrigation was applied for the whole season with moisture replacement, therefore for more information on the crop growth stage the crop should be subjected to different level of stress during its growth.
3. Similar research study using similar crop should also be conducted under green house production to obtained more information on the crop.

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Appendix I: Analysis of variance Table for yield of cucumber

| Source of Variation | Degree of Freedom | Sum of Squares | Mean Square | F-Value | Pr > F |
|---|---|---|---|---|---|
| Block | 2 | 59.01 | 29.51 | 1.59 | 0.279 |
| Irrigation | 3 | 4.4 | 1.47 | 0.08 | 0.969 |
| Error a | 6 | 111.31 | 18.55 | | |
| Mulch | 2 | 232.25 | 116.13 | 9.38 | 0.002 |
| Irrigation*Mulch | 6 | 93.36 | 15.56 | 1.26 | 0.331 |
| Error b | 16 | 198.15 | 12.38 | | |
| Total | 35 | 698.48 | | | |

Appendix II: Analysis of variance Table for number of fruits of cucumber

| Source of Variation | Degree of Freedom | Sum of Squares | Mean Square | F-Value | Pr > F |
|---|---|---|---|---|---|
| Block | 2 | 40603567 | 20301784 | 0.16 | 0.855 |
| Irrigation | 3 | 409327846 | 136442615 | 1.08 | 0.426 |
| Error a | 6 | 757750343 | 126291724 | | |
| Mulch | 2 | 1826406036 | 913203018 | 9.58 | 0.002 |
| Irrigation*Mulch | 6 | 260013717 | 43335620 | 0.45 | 0.832 |
| Error b | 16 | 1525925926 | 95370370 | | |
| Total | 35 | 4820027435 | | | |

Appendix III: Analysis of variance Table for fruit length of cucumber

| Source of Variation | Degree of Freedom | Sum of Squares | Mean Square | F-Value | Pr > F |
|---|---|---|---|---|---|
| Block | 2 | 7.39 | 3.7 | 1.64 | 0.27 |
| Irrigation | 3 | 94.75 | 31.58 | 14.04 | 0.004 |
| Error a | 6 | 13.5 | 2.25 | | |
| Mulch | 2 | 35.39 | 17.7 | 4.35 | 0.031 |
| Irrigation*Mulch | 6 | 24.83 | 4.14 | 1.02 | 0.449 |
| Error b | 16 | 65.11 | 4.07 | | |
| Total | 35 | 240.97 | | | |

Appendix IV: Analysis of variance Table for fruit circumference of cucumber

| Source of Variation | Degree of Freedom | Sum of Squares | Mean Square | F-Value | Pr > F |
|---|---|---|---|---|---|
| Block | 2 | 0.06 | 0.03 | 0.03 | 0.974 |
| Irrigation | 3 | 5.44 | 1.81 | 1.69 | 0.265 |
| Error a | 6 | 6.39 | 1.07 | | |
| Mulch | 2 | 1.72 | 0.86 | 1.26 | 0.309 |
| Irrigation*Mulch | 6 | 13.39 | 2.23 | 3.28 | 0.027 |
| Error b | 16 | 10.89 | 0.68 | | |
| Total | 35 | 37.89 | | | |

Appendix V: Analysis of variance Table for marketable fruit of cucumber

| Source of Variation | Degree of Freedom | Sum of Squares | Mean Square | F-Value | Pr > F |
|---|---|---|---|---|---|
| Block | 2 | 39711934 | 19855967 | 0.23 | 0.799 |
| Irrigation | 3 | 234430727 | 78143576 | 0.92 | 0.488 |
| Error a | 6 | 512277092 | 85379515 | | |
| Mulch | 2 | 1978600823 | 989300412 | 15.2 | 0.0002 |
| Irrigation*Mulch | 6 | 355281207 | 59213535 | 0.91 | 0.513 |
| Error b | 16 | 1041426612 | 65089163 | | |
| Total | 35 | 4161728395 | | | |

Appendix VI: Analysis of variance Table for unmarketable fruit of cucumber

| Source of Variation | Degree of Freedom | Sum of Squares | Mean Square | F-Value | Pr > F |
|---|---|---|---|---|---|
| Block | 2 | 10768175.6 | 5384087.8 | 0.21 | 0.815 |
| Irrigation | 3 | 45130315.5 | 15043439 | 0.59 | 0.642 |
| Error a | 6 | 152194787.4 | 25365798 | | |
| Mulch | 2 | 6652949.2 | 3326474.6 | 0.17 | 0.847 |
| Irrigation*Mulch | 6 | 70713305.9 | 11785551 | 0.6 | 0.73 |
| Error b | 16 | 316872428 | 19804527 | | |
| Total | 35 | 602331961.6 | | | |

Appendix VII: Average Water Applied (mm) in weeks after planting

| treatment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I100MRS | 40 | 40 | 40 | 15.2 | 25.9 | 28.1 | 27.9 | 31.2 | 29.9 | 19.8 | 15.4 | 12.0 | 10.0 | 9.8 | 346 |
| I100BPM | 40 | 40 | 40 | 18.4 | 15.8 | 12.2 | 29.1 | 21.9 | 18.9 | 17.8 | 13.2 | 12.1 | 11.3 | 8.3 | 299 |
| I100MNO | 40 | 40 | 40 | 20.1 | 32.1 | 31.5 | 38.2 | 35.0 | 33.4 | 35.3 | 30.5 | 28.8 | 11.2 | 10.2 | 436.3 |
| I75MRS | 40 | 40 | 40 | 12.8 | 11.0 | 7.8 | 20.9 | 17.9 | 15.7 | 11.1 | 16.4 | 6.7 | 8.7 | 11.4 | 260.4 |
| I75BPM | 40 | 40 | 40 | 13.1 | 15.0 | 19.6 | 15.3 | 13.4 | 14.3 | 10.8 | 9.2 | 8.1 | 7.5 | 7.1 | 253.4 |
| I75MNO | 40 | 40 | 40 | 16.4 | 14.9 | 23.2 | 35.1 | 29.4 | 20.5 | 18.9 | 11.0 | 13.5 | 6.0 | 5.0 | 286.9 |
| I50MRS | 40 | 40 | 40 | 6.2 | 8.8 | 13.1 | 16.4 | 14.5 | 8.0 | 6.7 | 7.4 | 6.4 | 5.0 | 2.6 | 215.1 |
| I50BPM | 40 | 40 | 40 | 10.5 | 6.5 | 11.1 | 18.1 | 15.9 | 16.1 | 11.5 | 7.9 | 5.4 | 5.5 | 2.3 | 230.8 |
| I50MNO | 40 | 40 | 40 | 18.9 | 11.1 | 14.3 | 16.5 | 18.0 | 12.2 | 17.9 | 10.2 | 11.8 | 5.0 | 5.5 | 261.4 |
| I25MRS | 40 | 40 | 40 | 6.9 | 8.1 | 4.4 | 7.3 | 6.4 | 7.6 | 4.9 | 2.9 | 2.5 | 2.8 | 2.4 | 176.2 |
| I25BPM | 40 | 40 | 40 | 8.4 | 4.7 | 8.9 | 7.6 | 8.7 | 4.3 | 5.2 | 2.8 | 1.9 | 2.4 | 2.1 | 177 |
| I25MNO | 40 | 40 | 40 | 8.2 | 4.9 | 7.6 | 8.8 | 4.7 | 6.6 | 6.8 | 3.0 | 4.0 | 2.2 | 2.0 | 178.8 |




Plate 1: Theta probe instrument taking reading on the field.



Plate 2: Cucumber plant with rice straw mulch



Plate 3: Experimental field layout with treatments