YIELD AND WATER USE RESPONSE OF WATERMELON UNDER DEFICIT IRRIGATION AND MULCH

BY

AISHATU GIDADO HALILU

(MSC/ENG/4423/2009-2010)

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL,

AHMADU BELLO UNIVERSITY, ZARIA

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTERS OF SCIENCE DEGREE IN AGRICULTURAL ENGINEERING

DEPARTMENT OF AGRICULTURAL ENGINEERING

AHMADU BELLO UNIVERSITY, ZARIA

MARCH, 2014

DECLARATION

I declare that to the best of my knowledge the work in this thesis entitled "**Yield And Water Use Response of Watermelon under Deficit Irrigation and Mulch" has been composed by me in the Department of Agricultural Engineering under the supervision of Prof. A.A Ramalan and Dr. M.K Othman.**

All information derived from the literatures has been duly acknowledged in the text and a list of references provided. No part of this thesis has been previously presented for another degree or diploma at any University.

Aishatu Gidado Halilu	**----------**	**----------**
Name of student	**Signature**	**Date**

CERTIFICATION

This thesis entitled "**Yield And Water Use Response Of Watermelon under Deficit Irrigation and Mulch" by Halilu Aishatu Gidado, meets the regulations governing the award of degree of Master of Science (Agricultural Engineering) of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.**

Prof. A.A. Ramalan	**…….**	**…….**
Chairman, Supervisory Committee	**Signature**	**Date**
Dr. M.K. Othman	**…….**	**……**
Member, Supervisory committee	**Signature**	**Date**
Prof. D.D. Yusuf	**…….**	**……**
Head of Department	**Signature**	**Date**
Prof. A.A. Joshua	**…….**	**……**
Dean of Post Graduate School	**Signature**	**Date**

DEDICATION

This work is dedicated to my parents Dr. M.G. Halilu, Mrs. A.G. Halilu and my husband Ibrahim Gidado for their sacrifice, love, support and encouragement throughout the entire programme.

ACKNOWLEDGEMENT

I wish to express my profound gratitude to my major supervisor, Prof. A.A. Ramalan and minor supervisor, Dr. M.K. Othman for their continued support, encouragement, constructive critisms, corrections and suggestions throughout the conduct of this research. Similarly my appreciation goes to Dr. H.E. Igbadun and Dr. M. Isiaka for their special interest and concern shown by way of continuous encouragement and making useful materials available for the success of this work, I am indeed grateful, Sirs.

Thanks are due to my lecturers and colleagues; Drs. U.S. Mohammed, M.A. Oyebode and M.A. Gwarzo. Proffessors A. El-Okene, O.J. Mudiare, S.Z. Abubakar, M.L. Suleiman and D.D yusuf. Engineers H. Ismail, A. Afolabi, M. Abdulsalam, M.K. Dalhat, I.B. Dalha, and M. Abubakar and the non academic staff of the Department of Agricultural Engineering for their concern and various levels of contribution throughout the period of this work. My special appreciation also goes to Musa Kurgwui of Irrigation Unit, Department of Agricultural Engineering for his assistance during the conduct of the experiment. It is my pleasure to acknowledge my parents and husband for the important role they played towards my success, of course without whose patience, perseverance, cheer and good humour the project would have been next to impossible, I am indeed grateful for their support in everything. To my dear brothers and sisters and the entire family, I say thanks and may God bless you all.

Above all, Glory and Honours be to the Most High, the Almighty Allah (SWA) for making this Programme a reality for me and for actualizing the concern efforts of individual contributors.

ABSTRACT

A field experiment was carried out from Feb-May 2012 at the irrigation Research Farm, Institute of Agricultural Research, Samaru, to determine the yield and water use response of watermelon under Deficit irrigation and mulch. The experiment consisted of four levels of irrigation water application depth of 100% (I_{100}), 75% (I_{75}), 50% (I_{50}) and 25% (I_{25}) replacement of moisture depleted and three mulch types (Rice straw mulch M_{RS}, Black polyethylene mulch M_{BP}, and No mulch M_{NO}) giving a total of 12 treatments laid in a randomized complete block design(RCBD). Water was applied to each basin using a calibrated short length PVC pipe serving as an orifice installed in each basin. The soil moisture was monitored throughout the crop growing season with gypsum block installed at three different depths (0 -15, 15 - 30 and 30 – 45 cm) below the soil surface. The experimental crop was watermelon, which was harvested at maturity, and then the fruits were counted and weighed. The yield obtained ranged from 7.38 t/ha to 58.49t/ha. The least yield value was obtained from the treatment with irrigation at 25% replacement of moisture depleted and No mulch ($I_{25}M_{NO}$) while the highest yield value was obtained with irrigation at 50% replacement of moisture depleted and black polyethylene mulch ($I_{50}M_{BP}$). The seasonal crop evapotranspiration ranged from 119 to 373 mm with the least value obtained at $I_{25}M_{NO}$ while the highest value was obtained at $I_{100}M_{NO}$. The highest crop water use efficiency and irrigation water use efficiency is at $I_{50}M_{BP}$ with 347.39kg/ha-mm and 268.55kg/ha-mm respectively while the least was at $I_{25}M_{NO}$ for crop water use efficiency with 33.56kg/ha-mm and at $I_{100}M_{NO}$ for irrigation water use efficiency with 32.09kg/ha-mm. The Ky values for the total growing season obtained were 1.3895 for M_{NO}, and no relationship for M_{RS} and M_{BP} was observed. The Kc values ranged from 0.42

to 0.55 for initial stage, 0.5 to 1.01 for development stage, 0.69 to 1.09 for mid season stage, 0.41 to 0.87 for late season stage respectively. Irrigation at 50% replacement of moisture depleted with black polyethylene mulch gives higher yield, thereby reducing the volume of water and increasing efficient use of water which is the major limiting factor during dry season farming in the region.

TABLE OF CONTENTS

Tittle page …… i

Declaration ……. ii

Certification …… iii

Dedication …… iv

Acknowledgement …… v

Abstract …… vi

Table of content …… viii

List of tables …… xii

List of figures …… xiii

List of plates …….. xiv

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study ……..…… 1

1.2 Statement of Problem …… 5

1.3 Objectives of Study……

1.4 Justification…….…… 5

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Crop Water Requirement …… 7

2.2 Evapotranspiration …… 8

2.2.1 Measurement of evapotranspiration and irrigation scheduling …… 9

2.3 Deficit Irrigation …… 10

2.4 Measurement of Soil Moisture ……. 12
2.5 Soil Moisture Measurement using Resistance Block …….. 13
2.6 Irrigation Water Requirement ……. 14
2.6.1 Irrigation depth ……. 15
2.6.2 Measurement of stream size ……. 17
2.7 Effects of Surface Mulches ……. 18
2.8 Crop Yield and Water Use …… 19
2.9 Characteristics of Experimental Crop: Watermelon…… 20
2.10 Cropwat …… 21

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area …… 22
3.2 Soil Data Analysis …… 23
3.3 Treatment and Experimental Design ……. 23
3.4 Field Operation ……. 27
3.4.1 Placement of mulch materials ……. 28
3.4.2 Water application ……..... 28
3.5 Measurement of Soil Moisture ……. 29
3.6 Determination of Actual Crop Evapotranspiration ……. 31
3.7 Reference Crop Evapotranspiration ……. 31
3.7.1 Crop coefficient ……. 32
3.7.2 Computation of water stress coefficient (Ks) ……. 33
3.8 Determination of Yield Response Factor …… 33
3.9 Dertermination of Crop Water Use and Irrigation Water Use Efficiencies …… 34
3.10 Crop Data and Analysis …….. 34

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Fruit number and Yield …… 36

4.1.1 Total and marketable yield …… 38

4.2 Irrigation Water Applied and Seasonal Water use …… 42

4.2.1 Crop Water Use Efficiency (CWUE) and Irrigation Water Use Efficiency (IWUE) ……. 46

4.3 Yield Response Factor …….. 49

4.3.1 Crop coefficient …….. 50

4.3.2 Water stress coefficients …….. 52

4.3.3 Fruit Yield – Seasonal Crop Water Use …… 53

CHAPTER FIVE

5.0 SUMMARY CONCLUSION AND RECOMMENDATIONS

5.1 Summary …… 57

5.2 Conclusion …… 58

5.3 Recommendation …… 59

References ……. 61

Appendix I Weather data for the 2012 irrigation cropping season…. 66

Appendix II Physical properties of the soil at the experimental site. 67

Appendix III Average water applied (mm) in weeks after planting…. 68

Appendix IV Average evapotranspiration mm in weeks after planting… 69

Appendix V Crop coefficient values in weeks after planting…… 70

Appendix VI Callibration curve of resistance block with gravimetric moisture content…….. 71

Appendix VII Sample moisture content obtained with resistance block… 72

LIST OF TABLES

Table 3.1 Treatment combinations of four irrigation levels and three mulch type …… 24

Table 4.1 Classification of watermelon fruit yield on the basis of weight in tons/hectare …….. 38

Table 4.1.1a Total and marketable fruit yield as affected by irrigation and mulch at samaru in 2011/2012 dry season on watermelon.…… 40

Table 4.1.1b Irrigation and mulch interaction on total and marketable yields of watermelon in Samaru 2011/2012 dry season. ……. 42

Table 4.2a Irrigation water applied and seasonal water use as affected by irrigation and mulch at samaru in 2011/2012 dry season on watermelon…… . 44

Table 4.2b Irrigation and mulch interaction on irrigation water applied and seasonal wateruse of watermelon in Samaru 2011/2012 dry season…… 46

Table 4.2.1a Means of crop water use efficiency and irrigation water use efficiency as affected by irrigation and mulch. …… 47

Table 4.2.1b Irrigation and mulch interaction on CWUE and IWUE of watermelon in Samaru 2011/2012 dry season. ……. 49

Table 4.3 Relative yield decrease and relative evapotranspiration deficit of watermelon in Samaru 2011/2012 dry season. …… 50

Table 4.3.1 Crop coefficient values for watermelon in Samaru 2011/2012 dry season …….. 51

Table 4.3.2 Water stress coefficient (K_s) for watermelon in Samaru 2011/2012 dry season ……..…….. 53

LIST OF FIGURES

Fig. 1 Experimental field layout …… 26

Fig. 2 Fruit yield and seasonal crop water use relationship for No mulch. …… 54

Fig. 3 Fruit yield and seasonal crop water use relationship for Rice straw mulch …….. 55

Fig. 4 Fruit yield and seasonal crop water use relationship for black polyethylene mulch ……. 56

Fig. 5 Callibration curve for resistance block with gravimetric moisture content…71

LIST OF PLATES

Plate 1 Experimental field layout with treatments …… 25

Plate 2. Watermelon plant mulched with Rice straw. …… 73

Plate 3. Watermelon plant mulched with Black polyethylene…… 74

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

Irrigation scheduling is commonly defined as determining when to irrigate and how much water to apply. Successful irrigation depends upon understanding and utilizing irrigation scheduling principles to develop a water management plan. Effective irrigation scheduling provides information to irrigation scheme managers for use in developing irrigation strategies on each field for efficient irrigation.

Scarce water resources and growing competition for water reduce its availability for irrigated agriculture. Achieving high water use efficiency is a primary challenge in irrigated agriculture. Irrigation practices and techniques aimed at maximizing crop production with minimum water utilization are fast evolving, and there is need for evaluation of these practices before adoption, which include the employment of techniques and practices that deliver a more accurate water supply to crops. (FAO, 2002, English and Raja 1996).

Studies are needed to increase the efficient use of the available water. Regulated deficit irrigation with mulching is one among many practices that is fast gaining ground, and it appears a very promising option at achieving the goal of more crops per unit volume of water, if properly adopted. 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).

Regulated deficit irrigation scheduling practice is a technique of withholding or skipping irrigation, or reducing the amount of water applied per irrigation at some stages of the growth with the aim of saving water, labor, and energy. This practice leads to some degree of moisture stress on the crop and likely reduction in crop yield (Smith *et al.,* 2002: Prichard *et al*. 2004; Zhang *et al*. 2004).

The objective of regulated deficit irrigation is to save water by subjecting crops to periods of moisture stress with minimal effects on the yields. The water stress results in less evapotranspiration by closure of the stomata, reduced assimilation of carbon, and decreased biomass production. The reduced biomass production has little effect on ultimate yields where the crop is able to compensate in terms of reproductive capacity (Stone *et al*. 2001).

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. Mulches are used to suppress weeds, reduce erosion, conserve soil moisture and modify soil temperature, structure and improve aeration (Plauborg *et al*. 1996, Hassan 1996). A better understanding of crop yield-water application interaction and the effects of irrigation levels and mulch (covering the soil surface) on the relationship between transpiration, evaporation and evapotranspiration for various crop is necessary to improve the management of irrigation water resources (Kadayifci *et al*. 2004).

Watermelon, *citrullus lanatus* (Thunb) is cultivated throughout the tropics and subtropics and has a worldwide distribution. Its world production had expanded from 2.9

to 3.7 million ha in the period from 1999 to 2003 (FAOSTAT data, 2004). In Nigeria, though there are no official figures recorded for its production, the crop has a wide distribution as a garden crop, while as a commercial vegetable production; its cultivation is confined to the drier savanna region of the Nigeria (Anon, 2006). It is a crop with high economic value and is grown and traded for export. The fruit is mainly eaten raw as a fresh juicy dessert. Most well drained soils, clayey or sandy, can be used to produce the crop. The crop is expected to have optimum yield in semi-arid region under irrigation where the climate may be conducive for its production. The fruit has high moisture content of about 92% and sometimes serves as a source of water for human consumption. Despite high water content, its seasonal water requirement is between 400 and 600 mm under tropical climate (FAO, 2001). It is of much importance to assess the effects of water stress and mulch on production, yield and quality of certain crops both at experimental level as well as at farm level and integrate new knowledge with the traditional farmers' knowledge through participating, research and extension (Kadayifci *et al*. 2004). Accurate knowledge of the impact of reduced water supply on yield and quality is required to define appropriate strategies to optimize crop production and economic benefits, while maintaining environmental requirements.

Many studies were reported on the irrigation of watermelon (Clark *et al*., 1996; Hussaini *et. al*., 2004; Erdem *et al*., 2003; Andrade-Junior et al., 1997; Clark and Maynard, 1996; El-Beheidi *et al*., 1990; Lee et al., 1995; Nerson *et al*., 1994; Oliveira, 1992; Pascale et al., 1998; Seo *et al*., 1997;). The available information shows that fruit yield response to water is usually highest when watermelon is adequately irrigated.

1.2 Statement of Problem

In arid and semi-arid climates of the tropics which have a long dry season, water resources for irrigated agriculture is increasingly becoming scarce and unaffordable. It is an established fact that one of the important factors limiting the development of agriculture in the semi-arid region is water. Samaru located within this region is one of agricultural areas in Zaria, Kaduna State. However, there are large potentially irrigatable lands which are not irrigated due to insufficient or lack of irrigation water, which led to the necessity of optimizing and managing the use of water for agricultural production (Oiganji, 2010). There is uncertainty as to the availability of water in adequate amounts and times, especially where storage facilities such as dams are absent. This necessitates development of water management strategy to avert water stress in crops; which if proven advantageous, could assist farmers as most of them are at subsistence level and they are economically weak with low ability to withstand risks.

Variation exists on the effects of deficit irrigation and mulches on crops which imply that the effects of deficit irrigation on a crop may vary with location. The variation in location may be due to climate which in turn dictates the evaporative demand of the crop and the soil type which determines the available water for plant uptake.

1.3 Objectives of Study

The general objective of the study is to evaluate the yield and water use response of watermelon (*Citrullus lanatus*) under different irrigation levels and different mulching materials.

The specific objectives are:

1. To determine the yield of irrigated watermelon field under different irrigation levels and mulch types.
2. To determine the water use efficiency of irrigated watermelon under different irrigation levels and mulch types.
3. To determine the yield response factor (K_y) and crop coefficient (Kc) of watermelon under different irrigation levels and mulch types.

1.4 Justification

A regulated deficit irrigation scheduling strategy and mulch application that can be suitable for crops grown in this locality is yet to be adopted, hence, a comprehensive assessment of impact of mulch and deficit irrigation scheduling strategies for crops grown in Samaru is needed. Watermelon performs better during the dry season under irrigation or residual moisture because excessive humidity in rainy season affects flowering and encourages the prevalence of pests and diseases. Hence, the crop is used for the study.

Information on combination of mulch type (material) and water application depth per irrigation, under deficit irrigation practice, that can maximize crop yield and water use efficiency for watermelon crop in Samaru is not known. So knowledge

on how the combination of mulch type and deficit irrigation practice affects soil water balance of a given field is required in order to arrive at a comprehensive recommendation on deficit irrigation practice to follow. Such assessment could help generate results that can be used to convince farmers, and other water resources users on the benefits associated with irrigation scheduling and mulching. The target of the study is to bring out the best combination of mulching material and the limit at which irrigation water can be reduced without adverse effect on crop yield.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Crop Water Requirement

A proper understanding of soil-water-plant relationship is required in order to obtain reliable information on the irrigation water requirement of a given crop which forms the basis for appropriate and sustainable water resources management. Crop water requirement is defined as the depth of water needed to meet the water loss through evapotranspiration or consumptive use of a disease-free crop, growing in large fields under non-restricted soil conditions including soil water and fertility and achieving full production potential under the given growing environment (Doorenbos and Pruitt, 1977). Evapotranspiration as defined by Hansen *et al.,* (1979) is the sum of two terms, transpiration which is the water entering plant roots and used to build plant tissue or being passed through leaves of the plant into the atmosphere, and evaporation, which is water evaporating from adjacent soil, water, or from the surfaces of leaves of plants. Weather parameters, crop characteristics, soil characteristics, management and environmental aspects are the major factors affecting crop evapotranspiration (Allen *et al.,* 1998). All agronomic crops have similar water use pattern. However, crop water use can change from growing season to growing season due to change in climatic variables (air temperature, amount of sunlight, humidity, wind) and soil differences between fields-root depth, soil water holding capacities, texture, structure, etc. Knowledge of water use patterns during the different growth stages has a major influence on how an irrigation system is designed and managed. Failure to recognize the water use patterns of crop may result in poorly managed water applications.

2.2 Evapotranspiration

Crop water use, also known as evapotranspiration (Et), is the water used by a crop for growth and cooling purposes. The term evapotranspiration refers to the rate of evapotranspiration of a disease-free crop growing in a field under optimal soil condition including, sufficient water and fertilizer, and achieving full production potential of the crop under the given growing environment (Doorenbos and Pruitt, 1977). The evapotranspiration process is composed of two separate processes: transpiration and evaporation. Transpiration is the water transpired or "lost" to the atmosphere from small openings on the leaf surfaces, called stomata. Evaporation is the water evaporated or "lost" from the wet soil and plant surfaces.

Significant evaporation can take place only when the soil's top layer or the canopy is wet. Once the soil surface is dried out, evaporation decreases sharply. Thus significant evaporation occurs after rain or irrigation. Furthermore as the growing season progresses and canopy cover increases, evaporation from the wet soil surface gradually decreases. When the crop reaches full cover, approximately 95% of evapotranspiration is dues to transpiration and evaporation from the crop canopy where most of the solar radiation is intercepted. Crop water use is influenced by prevailing weather conditions, available water in the soil, crop species and growth stages. At full cover, a crop will have the maximum Et rate (reference Et) if soil water is not limited; if the soil root is at field capacity. Full cover is a growth stage at which most of the soil is shaded by the crop canopy.

2.2.1 Measurement of evapotranspiration and irrigation scheduling

Evapotranspiration measurement methods can be broadly classified into two; Those that measure actual evapotranspiration (ETa) and those that measure potential evapotranspiration (ETp) cited by Bungwon (1993). The principle of measuring actual evapotranspiration as described by Micheal (1978) are lysimeter experiment, field experimental plots, soil moisture depletion and water balance methods. The potential evapotranspitration approach for measuring crop evapotranspiration relates the magnitude and variation of evapotranspiration to one or more climatic factors (temperature, day length, humidity, wind, sunshine, etc.). This approach broadly attempts to estimate evapotranspiration by empirical methods and estimation of evapotranspiration from evaporation data. The most commonly used empirical methods in estimating potential evapotranspiration are Blaney-criddle method Thornthwaite Penman method, modified Penman method, FAO Penman-Monteith method, Christiansen method, Hargreaves method, Jansen-Haise method, and pan evaporation methods respectively (Micheal 1978).

Irrigation scheduling is the process of determining when to irrigate and how much water to apply per irrigation. Several methods are used for determining when to irrigate and they are classified as follows: plants indicators and soil indicators, calculation method and water budgeting technique. Using plant and soil indicators involve monitoring the behavior of plant and soil to determine when to irrigate. In the calculation method and the water budgeting technique, the irrigation interval is determined from the total available soil water and the daily crop consumptive use (Doorenbos and Kassam 1979).

2.3 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 is an optimization strategy in which irrigation is applied during drought-sensitive growth stages of a crop. Outside these periods, irrigation is limited or even unnecessary if rainfall provides a minimum supply of water. Water restriction is limited to drought-tolerant phonological stages often the vegetative stages and the late ripening period (Sam and Dirk 2009). It is a well known fact that certain growth stages of crops are more sensitive to water deficits than others, knowledge of the marginal productivity of water allocated to each crop at different stages of its growth is thus required to arrive at an optimal sets of decisions.

Doorenbos and Kassam (1979) stated that the relationship between crop yield and water deficits, on one hand, and maximum and actual crop yield on the other can be quantified. Water deficits in crops and the resulting water stress on the plant have effects on crop evapotranspiration and crop yield. When crop water requirements are fully met from available water supply the actual evapotranspiration will be equal to the maximum evapotranspiration, when water supply is insufficient the actual evapotranspiration is likely to be less than maximum evapotranspiration. More so, where economic conditions do not restrict crop production, actual crop yield might be equal to the maximum yield when full irrigation are met, when full irrigation are not met, the actual yield might be less than maximum yield. However, when moisture stress is not severe, the adverse effect on crop yield is minimal and there can be an appreciable increase in crop water use efficiency

especially when there is reduction in water losses due to evaporation, deep percolation and runoff (Bucks *et al*., 1990, Panda *et al.*,2004).

Water is applied to crop when the crop comes under water stress severe enough to reduce crop yield or quality. The level of stress that may cause reduction in crop yield or quality depends on the kind of crop and its stages of development which varies during the growing season as the crop matures. The goal of regulated deficit irrigation provides a means of increasing crop water use efficiency by reducing the amount of water at irrigation (Kirda, 2002). 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) concluded 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

……..2.1

Where Y_a and Y_m are the actual and maximum yield in kg/ha.

Eta and Etm are the actual and maximum evapotranspiration in mm

K_y 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 yield. This approach and the calculation procedures for estimating yield response to water were published in the *FAO Irrigation and Drainage Paper* No. 33 (Doorenbos and Kassam, 1979), which was considered one of FAO's milestone publications, and were used worldwide for a broad range of applications.

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.

2.4 Measurement of Soil Moisture

Soil moisture is determined before and after irrigation with some measurement between irrigations in the major root zone. The soil is usually sampled 2-4 days after irrigation and just before the next irrigation (Micheal, 1978). The amount of water be applied with each irrigation depends primarily on the soil and the amount of water it can retain for plant use, referred to as total available water (TAW). The amount of water removed from the soil by plant since the last irrigation or rainfall is referred to as the depletion volume.

Depletion of available soil water in the effective root zone depth can be estimated by an equation cited by Igbadun *et al*.,(2008) as:

Depletion (%) = 100 × – ——— ……2.2

Where fci is gravimetric soil moisture content (g/g) at field capacity in the ith layer;

wcpi is gravimetric soil moisture content at wilting point in the ith layer

Gmci is gravimetric soil moisture content at the time of sampling; n is the number of layers in the effective root zone.

Soil water content can be measured by direct and indirect methods. The direct method measures soil water potentials (suction) using resistance blocks, tensiometer, and thermocouple psychrometer and pressure membrane apparatus. While the indirect method include the use of models such as Penman, Blaney criddle, Thornthwaite etc.

2.5 Soil Moisture Measurement using Resistance Block

Resistance blocks are commonly made of gypsum which is placed in contact with the soil at different depths. The resistance block absorb moisture from the soil, and a resistance of a given block to an electric current is related to the water it absorbs because the moisture content varies with the soil suction. An approximate amount of moisture content in the soil can be obtained by calibrating the resistance block readings with soil moisture content. However the life span of a gypsum block depends on the soil type, soil

wetness, erosion, site specific factors and salinity. When gypsum block begins to give a very high resistance value at higher moisture content it shows that it has started to fail.

The Gypsum blocks could dissolve over a period of time generally lasting for two to three seasons in good condition. Large errors, up to 100% can occur due to slow equilibrium of blocks with actual soil potential. The dependence of resistance on the block temperature, effect of hysteresis on the calibration of block (if undertaken to improve accuracy) and actual contact with the soil and block pores by fine material (e.g silt or clay particles), (Stenizer 2004; White and Zegelin 1994; Mahdi, 2000).

The advantages of using the gypsum block method to determine soil moisture are that no soil sample collection is required, more frequent readings for the same field and the same location can be taken, it is sensitive over a wide range for field use and it saves time. Similarly, gypsum blocks can be used to check soil moisture during the growing season and determine the depth of soil that has been recharged from rainfall. However, accuracy is limited under saline and dry conditions. Accuracy requires that the blocks must have good contact with the soil.

2.6 Irrigation Water Requirement

The irrigation water requirement is the water, which must be applied through the irrigation system to ensure that the plant grows to its full potential. When irrigation is the sole source of water supply for plant, then the irrigation requirement should be equal to the crop evapotranspiration (crop water requirement). Generally, the irrigation water requirement is greater than crop water requirement to allow for inefficiencies (water losses) during the application of irrigation water (unavoidable losses), and the quantity of

water required for special operation such as land preparation, leaching, etc (Micheal, 1978).

……2.3

Where

IR = The irrigation requirement of the crop, cm

CWR = The crop water requirement, cm

ER = The effective rainfall, cm

S = The 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.

2.6.1 Irrigation depth

Depth of irrigation is a function of the water retentive capacity of the root zone soil and the extent of soil water depletion at time of irrigation. It refers to the depth to 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 (Majumdar, 2006). The soil moisture just before irrigation must be known to calculate the net depth of water required to be applied. It is calculated by Eq.2.4.

——— 2.4

Where,

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

Fc = soil moisture at field capacity of the layer of soil in percent by weight

Mb = soil moisture of a given layer of soil just before irrigation, percent by weight

As = bulk density of soil, g/cm

D = depth of the layer of soil in the root zone, cm.

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

…….. 2.5

— ……2.6

Where,

= volume of water to be applied, m^3

= area to be irrigated, m^2

gross depth, m

application efficiency which is considered 100%

Application time is obtained using the relation:

..... 2.7

Where,

Discharge in litres/sec

= volume of water to be applied, litres

= Application time, seconds

2.6.2 Measurement of stream size

Major water measuring methods are classified into four categories: volumetric measurement, velocity-area method, measuring structures, and Tracer method (Michael, 1978). Volume method of water measurement is to collect the flow in a container of known volume for a measured period of time. Here, bucket and wrist watch may be used to estimate the discharge. In velocity area method, the rate of flow passing a point in a pipe or an open channel is determined by multiplying the cross-sectional area of the flow section at right angles to the direction of flow by the average velocity of water. The cross-sectional area is directly measured while the velocity is generally measured with a current meter or approximately estimated using the floating method.

Water flow measurements are also done using hydraulic structures. The commonly used structures for measurement of irrigation water in the farm are weirs, parshall flumes, orifices and meter gates. In these structures, the rate of flow is measured directly by making a reading on a scale which is a part of the structure and computing the discharge

rate from standard tables or calibration curves/equations prepared specially for the hydraulic structures.

2.7 Effects of Surface Mulches

There have been many research works on the effects of mulch application on crop water requirement. Mulching was found to reduce the rate of evapotranspiration in addition to the increase in infiltration rate thereby increasing water use efficiency. In soil management practice, mulching has been reported to influence organic matter content, activity of micro-organisms, availability of soil nutrients, control of erosion and soil compaction (Stowell, 2000).

In arid and semi-arid regions, crops are sometimes subjected to thermal and moisture stresses during their growing period. Such adverse conditions reduce the growth potential and subsequent yield of the crops in addition to loss of water through excessive soil evaporation.

Generally, mulching is aimed at improving soil moisture conditions especially in arid and semi-arid regions, increasing crop yield, suppressing weeds, reducing erosion, conserving soil moisture, modifying soil temperature and structure. The high soil moisture content from increased infiltration and reduced soil evaporation associated with mulching result in reducing crop water requirement thereby increasing water use efficiency, especially during irrigation season when water is the major limiting factor in crop production.

Mulches can be composed of plant materials or they may synthetic consisting of plastic sheets (Allen *et al.,* 1998). Plastic mulch can be transparent, white or black. Plastic mulches substantially reduce evaporation of water from the soil surfaces, especially under deficit irrigation (Allen et al., 1998). In using organic mulches, the depth of organic mulch and the fraction of the soil surfaces covered will affect the amount of reduction in evaporation from the soil surface. The advantage of plastic mulch are: increase soil temperature to conducive level, reduce evaporation, cleaner product, reduced weed problem. However the disadvantages are: high cost of removal, greater initial costs, and increased cost of management.

Soil micro-organism are active in the plant residue types of mulches especially at the surface where both the soil and mulch are moist. The nitrogen fixing bacteria require nitrates in their breaking down organic matter. Plastic mulch has been reported to increase output and farm revenue (Mugalla *et al.,* 1996). It is observed that as the colour of the mulch changes from black to white, soil temperature under mulch decrease (Graham *et al.,* 1995). Many researchers have reported a significant increase in vegetation and yield of different crops using mulch (Chen and Katan, 1980). Mulching the soil surface reduces evaporation and increase the amount of water stored in the soil profile (Mahrer *et al.,* 1984).

2.8 Crop Yield and Water Use

The relationship between crop yield and water use is very 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.

2.9 Characteristics of Experimental Crop: Watermelon

Watermelon (*Citrullus lanatus*) is native to the dry areas in tropical and sub-tropical Africa. The crop can survive the desert climate when groundwater is available and the fruit sometimes serves as a source of water for human consumption. World production is about 77.5 million tons fruit from 3.1 million ha (FAOSTAT, 2001). The crop prefers a hot, dry climate with mean daily temperatures of 22 to 30°C. Maximum and minimum temperatures for growth are about 35 and 18°C respectively. The optimum soil temperature for root growth is in the range of 20 to 35°C. Fruits grown under hot, dry conditions have a high sugar content of 11 percent in comparison to 8 percent under cool, humid conditions. The crop is very sensitive to frost. The length of the total growing period ranges from 80 to 110 days, depending on climate (FAO. 2002).

The crop prefers a sandy loam soil texture with pH of 5.8 to 7.2. Cultivation in heavy textured soils results in a slower crop development and cracked fruits. For high production fertilizer requirements are 80 to 100 kg/ha N, 25 to 60 kg/ha P and 35 to 80 kg/ha K. The crop is moderately sensitive to salinity. Yield decrease due to salinity appears to be similar to that of cucumber, or: 0% at ECe 2.5 mmhos/cm, 10% at 3.3, 25% at 4.4, 50% at 6.3 and 100% at ECe 10 mmho s / cm. Watermelon is normally seeded directly in the fields. Thinning is practiced 15 to 25 days after sowing. Spacing between plants and rows varies from 0.6 x 0.9 to 1.8 x 2.4 m. Seeds are sometimes placed on hills spaced 1.8 x 2.4m. In areas prone to frost, sowing time is dictated often by the occurrence of frost; sometimes black plastic mulch is used for frost protection.

2.10 Cropwat

CROPWAT is a decision support tool developed by the Land and Water Development Division of FAO. CROPWAT 8.0 for Windows is a computer program for the calculation of crop water and irrigation water requirements based on soil, climate and crop data. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. CROPWAT 8.0 can be used to evaluate farmers' irrigation practices and to estimate crop performance under both rainfed and irrigated conditions. All calculation procedures used in CROPWAT 8.0 are based on the two FAO publications of the Irrigation and Drainage Series, namely, No. 33 titled "Yield response to water" and No. 56 "Crop Evapotranspiration - Guidelines for computing crop water requirements".

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The experiment was conducted during dry season from February to May 2012 at the Irrigation Research Farm of the Institute for Agricultural Research, Samaru-Zaria, Nigeria. The study area is located at 11°11'N and 7°38'E, with an altitude of 686 m above sea level and is located within the Northern Guinea Savannah ecological zone of Nigeria with a semi-arid climate. The area has three distinct seasons; 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. The on-set of rains in the area is in May, but effective rainfall begins in late June and falls till early October, with a peak in August. The mean annual rainfall depth is 1150 mm, with an average peak of 650 mm in August, as obtained from the Meteorological Office of the Institute for Agricultural Research (I.A.R). The cool-dry (harmattan) and hot dry seasons are the months for irrigation. (Igbadun 1997; Ramalan and Nwokeocha, 2000; Oiganji 2010).

The meteorological data for the period of the study was obtained from the Institute's Meteorological station located at the Farm. The monthly maximum temperature ranged from 32-39°C, while minimum temperature ranged from 13-23.1°C. A total rainfall of 16.5 mm was received during the period of the experiment as presented in Appendix I.

3.2 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 to determine the moisture content at field capacity and at wilting point conditions using pressure plate membrane. The bulk density at the different depth was also determined as presented in Appendix II.

3.3 Treatment and Experimental Design

The experimental crop was watermelon. The treatments consisted of three mulch types (rice straw mulch, black polythene and no mulch) and four irrigation levels (100%, 75%, 50% and 25% replacement of moisture depleted) replicated three times making a total of 36 plots and laid out in a randomized complete block design (RCBD). The blocks were separated by a distance of 1.5 m, while the basins in each block were separated by a distance of 1.0 m which served as buffer to minimize lateral movement of water from one basin to another. The description of the experimental treatments and field layout are shown in Table 3.1, Plate 1 and Figure 1 respectively. The crop was planted on 14th Feb. 2012 in 2.5 m by 4.5 m well-leveled basins each of 11.25 m^2 plot and a total area of 782 m^2.

Table 3.1: Treatment combinations of four irrigation levels and three mulch type.

Treatment No.	**Treatment combinations**	**Description of treatment combination**
1.	$I_{100}M_{RS}$	Irrigated at100% replacement of soil moisture depleted with rice straw mulch.
2.	$I_{100}\ M_{BP}$	Irrigated at 100% replacement of soil moisture depleted with black polythene mulch.
3.	$I_{100}M_{NO}$	Irrigated at 100% replacement of soil moisture depleted with no mulch.
4.	$I_{75}\ M_{RS}$	Irrigated at 75% replacement of soil moisture depleted with rice straw mulch.
5.	$I_{75}\ M_{BP}$	Irrigated at 75% replacement of soil moisture depleted with black polythene.
6.	$I_{75}\ M_{NO}$	Irrigated at 75% replacement of soil moisture depleted with no mulch.
7.	$I_{50}\ M_{RS}$	Irrigated at 50% replacement of soil moisture depleted with rice straw mulch.
8.	$I_{50}\ M_{BP}$	Irrigated at 50% replacement of soil moisture depleted with black polythene mulch.
9.	$I_{5o}\ M_{NO}$	Irrigated at 50% replacement of soil moisture depleted with no mulch.
10.	$I_{25}\ M_{RS}$	Irrigated at 25% replacement of soil moisture depleted with rice straw mulch.
11.	$I_{25}\ M_{BP}$	Irrigated at 25% replacement of soil moisture depleted with black polythene mulch.
12.	$I_{25}\ M_{NO}$	Irrigated at 25% replacement of soil moisture depleted with no mulch.



Plate 1: Experimental field layout with treatments

3.4 Field Operation

The field experiment was carried out from Feb. to May. 2012. The entire site was ploughed and harrowed to facilitate deeper rooting once to a depth of 15 cm and moisture penetration. Plots were marked out and made into basins with waterways between pairs of basins. Three watermelon seeds were planted per hole at a depth of 3 cm with a square spacing of 1.5 m on 14th Feb. 2012. Seedlings were thinned to one plant per stand at two weeks after planting. NPK fertilizer was applied in split two doses; half at planting and the other half at 4 weeks after planting at a rate of 100k Kg/ha of N, 60 Kg/ha of P, and 60 Kg/ha of K as recommended by the FAO (2002). Irrigation was done before planting to facilitate soil leveling and a second irrigation just after sowing. In each plot of 2.5 m x 4.5 m, a total of six stand of watermelon was planted. Equal depth of irrigation water of 40 mm was applied for four weeks before the proposed treatment levels were imposed. This allowed proper establishment of the crop. There were ten irrigations cycles from the time the treatments were imposed. Different doses of water were applied in accordance in accordance to the amount of water depleted in each of the irrigation cycles.

Weeding was done manually at three weeks after planting and thereafter every two week throughout the growing season except for the mulched plots. An incidence of disease Downy mildew caused by *Pseudoperospora (durba)* occurred during the experimental period thereby affecting some of the plants. However, the disease was controlled by applying Cypermethrine and Imiforce using a knap sack sprayer. The crop attained physiological maturity at 90 days after planting and harvesting was done three times manually through hand picking.

3.4.1 Placement of mulch materials

At four weeks after planting, when the watermelon crop was fully established, the mulch treatments were imposed. Thus, black polyethylene mulch of low density was cut into a 3 m by 5 m sheet and spread on the 2.5 m by 4.5 m plot. Therefore a small hole was made for each of the watermelon plant stand. 6 kg of rice straw mulch was applied uniformly on each basin according to treatment description. The weight of 6 kg was adopted based on trial for good coverage of the plot with the mulching material.

3.4.2 Water application

Surface irrigation method was used to convey water through field ditches which ran parallel to the basins. Water was released from the main canal into a lateral ditch which conveyed the water by gravity to the field ditches which service the basins. A PVC pipe of 5 cm diameter and 50 cm length was used for the supply of water into each basin. The pipe was installed at each plot to give a free orifice flow. Graduated gauge was placed at the water inlet of each basin to measure the depth of water flowing through the pipe. Thus, the discharge through the pipe into the basin was computed with Eq. 3.1 and the depth of water applied was monitored using a stop watch to know the time taken to apply the desired depth of water with Eq. 3.2.

The plots were of size 2.5 m by 4.5 m so the spread of water within each basin was even. Plastic cork was used to cut off the flow of water into the plots at the end of the calculated time and to close the inlets.

$Q = C_d A \sqrt{\quad}$ ……3.1

Where Q is the discharge in m^3/sec,

C_d = coefficient of discharge taking to be 0.65,

A = the Area of the orifice in m^2,

h = the height of water above the orifice in m,

…….3.2

Where A = the Area of the basin in m^2,

n = the application efficiency which was assumed to be 100% as there is no deep percolation or runoff.

d = the depth of water applied to the basin with respect to percentages of water depleted,

t = the time in sec.

3.5 Measurement of Soil Moisture

The amount of water depleted from the soil was determined with the use of gypsum blocks as shown in Appendix VII. Thus, the soil moisture was monitored throughout the growing season. Installation of gypsum blocks was done by soaking the blocks in water for 24 hours to saturate them. A circular hole of 4 cm diameter was made with the use of an auger on each plot at different depths of 10 cm, 20 cm and 35 cm in the soil profile. The gypsum blocks were pushed into the holes in each plot, making sure that there was a good contact between the soil and the gypsum blocks with the wire lead protruding from the gypsum block to the top of the soil. Reading of the resistance to flow was taken with the

aid of an electrical resistance meter; measurement of soil moisture at different depth in the soil profile was carried out. Three pieces of gypsum blocks were installed at a depth 10, 20 and 35cm for each plot so soil moisture content measurement were made by connecting a resistance meter through the electrode of the gypsum blocks. The measurements were made at depth 10, 20 and 35cm below the soil surface represent soil profile depth of 0-15cm, 15-30cm and 30-45cm respectively.

Soil samples were collected from the various depths for gravimetric moisture content determination. Regression analysis were done on volumetric moisture content from gravimetric method on the ordinate axis and their corresponding values indicated by the resistance blocks on the abscissa axis at various depths, and a straight line was fitted to the graph (Appendix VI) to obtain the calibration curve and the regression model equation which was found to be:

$Y = -0.6145x + 21.169$ ……3.3

$R^2 = 0.904$

This expression was used to estimate the soil moisture content in g/g (Y) as a fuction of the resistance in ohms (x).

Soil moisture content was monitored throughout the growing season, soil moisture measurements were carried out twice a week and was done two days after an irrigation event and on the day before the next irrigation.

3.6 Determination of Actual Crop Evapotranspiration

The actual crop evapotranspiration was calculated from measured soil moisture content data using the gypsum blocks using of Eq. 3.4 (Michael, 1978).

Eta = ——— ……...3.4

Where

ETa = Actual crop evapotranspiration, mm/day

M1 = gravimetric moisture content at the first sampling in the ith layer g/g,

M2= gravimetric moisture content at the second sampling in the ith layer g/g

Di = the depth of ith layer (mm).

Bdi = bulk density of the ith layer.

n = number of layers within the soil profile.

3.7 Reference Crop Evapotranspiration

The reference crop evapotranspiration was estimated with the use of CROPWAT 8.0 software. The weather data on temperature, sunshine, relative humidity and wind speed were obtained from the Institute for Agricultural Research (IAR), Ahmadu Bello University, Samaru Zaria. The data were from Jan. to May 2012.

3.7.1 Crop coefficient

Crop coefficient was calculated by relating measured crop evapotranspiration and the estimated reference crop evapotranspiration using the FAO-Penman-Monteith equation; (Allen *et al.,* 1998).

K_c = —— ……3.5

Where K_c is the crop coefficient

Eta is the actual evapotranspiration of the fully irrigated treatment mm/day

Eto is the reference crop evapotranspiration mm/day

The crop coefficient of the deficit irrigated treatments (referred to as Kc deficit) was computed as the ratio of the average daily CWU of the deficit irrigated treatments to the average daily ETo on weekly basis.

Kc deficit = ———— ……..3.6

Where Eta deficit is the actual evapotranspiration for the deficit irrigated treatment, mm/day.

3.7.2 Computation of water stress coefficient (Ks)

The water stress coefficient (Ks) integrates the crop and soil factors that make the actual crop water use of the deficit irrigated condition differ from crop water use under fully irrigated condition. The relationship was expressed by (Allen et al., 1998) as:

K_s = ———— ……..3.7

Where Eta deficit is the actual evapotranspiration for the deficit irrigated treatment mm/day.

Eta is the actual evapotranspiration of the fully irrigated treatment mm/day.

The values Ks for the four growth stages of the crop were computed by finding averages of the weekly coefficients values for growth stages.

3.8 Determination of Yield Response Factor

Doorenbos and Kassam (1979) introduced the yield response factor (K_y) which relates the decline in yield per unit decrease in evapotranpiration to describe the relationship between evapotranspiration deficit (1 – Eta/Etm) and yield reduction (1 – Y_a/Y_m).

(1 - —) = K_y (1 - ——) ……3.8

Where

Ya = actual yield for each treatment (Kg/ha)

Ym = maximum yield obtained (Kg/ha)

Eta= actual evapotranspiration for each treatment (mm)

ETm= maximum evapotranspiration obtained (mm)

Ky = yield response factor.

The computed K_y values in this research were grouped into mulch levels to observe the relationship between the relative yield decrease with the relative evapotranspiration deficit to ascertain if they are of the same range.

3.9 Dertermination of Crop Water Use and Irrigation Water Use Efficiencies

The crop water use efficiency (CWUE) is commonly expressed as the economic yield divided by the seasonal crop water use (seasonal evapotranspiration) (Flenet *et al.*,1996), and the irrigation water use efficiency (IWUE) is expressed as the economic yield divided by the total irrigation water applied (Ibragimov *et al.,* 2007, Howell *et al.,* 1990) were evaluated.

3.10 Crop Data and Analysis

Crop yield parameters such as number of fruits per plot, average weight of fruit, total yield and marketable yield were collected during harvest. The fruits from each plot were classified into weight sizes (small, medium and large) of 0-2 kg, 2-4 kg and 4-6kg

respectively. The seasonal water use and irrigation water applied were also recorded. The data collected were statistically analyzed using the analysis of variance procedure of SAS. Significant treatment means were compared using Duncan Multiple Range test (DMRT) at 5% level of probability.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Fruit number and Yield

The effect of various treatments on watermelon fruit number and yield is shown in Table 4.1; the watermelon fruit yield per plot from each treatment was classified on the basis of weight sizes as small, medium and large with 0-2 kg, 2-4 kg and 4-6 kg respectively to see the contribution of each class to the total yield.

The watermelon fruit yield obtained from small class ranges from 1.52 t/ha to 6.67 t/ha. The least yield values was obtained from treatment irrigated with 100% replacement of moisture depleted and rice straw mulch (I_{100} M_{RS}), while the highest value recorded was obtained from treatment with 50% replacement of moisture depleted and black polyethylene mulch (I_{50} M_{BP}). For the medium class size the fruit yield obtained ranged from 19.64 t/ha to 19.64 t/ha, the highest fruit yield was obtained from treatment with 50% replacement of moisture depleted and black polyethylene mulch (I_{50} M_{BP}) while the least yield was obtained from treatment irrigated at 25% replacement of moisture depleted and no mulch (I_{25} M_{NO}). For the large class classification, watermelon fruit yield obtained ranged from 0 t/ha to 32.18 t/ha with the highest yield recorded at treatment irrigated with 50% replacement of moisture depleted and black polyethylene mulch while the least was treatment irrigated at 25% replacement of moisture depleted and no mulch. The total net harvested fruit yield of 12.07% was obtained from 0-2 kg classified as small, 35.68% obtained from 2-4 kg classified as medium and 52.25% of total net harvest was obtained from 4-6 kg classified as large. The large size attracts higher profit to farmers as they are

found to be more attractive to customers while small size attracts less profit as some of the fruits may not be ripe for consumption. The number of fruit per ha ranges from 5333/ha to 20444/ha with the highest number of fruit obtained from the treatment irrigated with 50% replacement of moisture depleted and black polyethylene mulch while the least was obtained from treatment irrigated with 25% replacement of moisture depleted and no mulch.

The total yield obtained per plot ranges from 7.38 t/ha to 58.49 t/ha. The 50% depleted moisture with black polyethylene mulch had the highest yield 58.49 t/ha while the treatment with 25% depleted moisture replacement without mulch resulted in the least yield of 7.38t/ha. This implies that mulching is beneficial while replacement of moisture depletion beyond 50% has adverse effect on yield of watermelon. Interestingly it was observed that the 100% replacement of moisture depleted did not produce the highest yield. This might be as a result of high moisture in the soil causing excessive humidity conducive for pest and diseases. The highest yield of 58.49 t/ha was higher than the commercial yield of 25 to 30t/ha under irrigation as reported by the Food and Agricultural Organization (FAOSTAT 2001). Report of 2010 agricultural performance Survey conducted by NAERLS showed that farmers obtained an average yield of 23t/ha (NAERLS, 2010 APS) which is lower than the highest yield obtained in this research.

Table 4.1: Classification of watermelon fruit yield on the basis of weight in tons/hectare

Treatments	Small (0 - 2kg)	Medium (2 - 4kg)	Large (4 – 6kg)	Total yield (t/ha)	Number of fruit/ha
$I_{100}M_{RS}$	1.52	5.16	21.87	28.55	9778
$I_{100}M_{BP}$	2.49	15.64	10.67	28.8	13333
$I_{100}M_{NO}$	1.6	6.67	6.67	14.94	6222
$I_{75}M_{RS}$	2.84	10.22	27.29	40.35	13333
$I_{75}M_{BP}$	3.2	14.84	22.49	40.53	14222
$I_{75}M_{NO}$	2.31	6.13	12.89	21.33	8889
$I_{50}M_{RS}$	2.13	15.64	21.06	38.83	9778
$I_{50}M_{BP}$	6.67	19.64	32.18	58.49	20444
$I_{50}M_{NO}$	6.22	10.49	6.67	23.38	7111
$I_{25}M_{RS}$	5.24	10.58	10.67	26.49	7111
$I_{25}M_{BP}$	4.27	4.44	8.44	17.15	8889
$I_{25}M_{NO}$	3.29	4.09	0	7.38	5333

Where I_{100}, I_{75}, I_{50} and I_{25} are 100%, 75%, 50% and 25% replacement of moisture depleted respectively. M_{RS}= rice straw mulch, M_{BP} = polythene mulch, M_{NO}= No mulch.

4.1.1 Total and marketable yield

The marketable yield is the fraction of the total yield that can be commercialized, that is attracts values for the market.The total and marketable fruit yield are presented in Table 4.1.1a. the result are significantly different at 5% probability with respect to irrigation levels and mulch materials. Under irrigation treatment the highest total and

marketable fruit yields were obtained at 50% replacement of moisture depleted (I_{50}) with 39.72 t/h and 36.41 t/ha, respectively followed by 75% replacement of moisture depleted (I_{75}) with 33.81 t/h and 31.14 t/ha then 100% replacement of moisture depleted (I_{100}) with 23.94 t/ha and 21.17 t/ha. The least value obtained was at the treatment irrigated at 25% replacement of moisture depleted (I_{25}) with 16.12 t/ha and 12.84 t/ha.

Under mulching, it can be noticed that the highest total and marketable fruit yield was obtained by black polyethylene (M_{BP}) mulched treatment which recorded 35.53 t/ha and 32.30 t/ha followed by rice straw mulch (M_{RS}) with 33 t/ha and 30.09 t/ha then the least was treatment with no mulch (M_{NO}) 16.68 t/ha and 13.78 t/ha. The highest yield obtained in this research is higher than the highest yield Hussaini etal., (2004) obtained (33.4t/ha) in 2000 but lower than the highest yield in 2001 and 2003 which recorded 43.1t/ha and 92.4t/ha respectively in Kadawa, Kano, Nigeria.

Table 4.1.1a Total and marketable fruit yield of watermelon as affected by irrigation and mulch in Samaru during 2011/2012 dry season.

Treatment	Marketable Yield (t/ha)	Total Yield (t/ha)
Irrigation		
I_{100}	21.17c	23.94c
I_{75}	31.14b	33.81b
I_{50}	36.41a	39.72a
I_{25}	12.84d	16.12d
SE	0.55	0.262
CV	6.47	2.77
Significance	**	**
LSD	2.78	1.33
Mulching		
M_{RS}	30.09b	33.00b
M_{BP}	32.30a	35.53a
M_{NO}	13.78c	16.68c
SE	0.474	0.227
CV	6.47	2.77
Significance	**	**

Means followed by the same letter(s), in a column of any treatment group are not significantly different at 5% level. ** = highly significant difference. Where I_{100}, I_{75}, I_{50} and I_{25} are 100%, 75%, 50% and 25% replacement of moisture depleted respectively. M_{RS}= rice straw mulch, M_{BP} = polythene mulch, M_{NO}= No mulch.

The rice straw mulch recorded higher total yield with 28.83 t/ha from table 4.1.1b followed by black polyethylene mulch with 28.21 t/ha which was similar with the M_{RS} then no mulch(M_{NO}) with 14.78 t/ha when irrigation was given at 100% replacement of moisture depleted. However, irrigation at 75% and 50% replacement of moisture depleted, polyethylene mulch recorded higher yield of 41.09 t/ha and 57.39 t/ha followed by rice straw mulch with 39.02 t/ha and 38.52 t/ha compared to the no mulch with 21.3 t/ha and 23.35 t/ha. At 25% replacement of moisture depleted, the no mulch has the least value with 7.29 t/ha followed by the black polyethylene mulch with 15.44 t/ha and the highest was the rice straw mulch with 25.63 t/ha.

When mulching with rice straw mulch, it was observed that irrigation at either 50% or 75% replacement of moisture depleted resulted to higher total fruit yield followed by 100% replacement of moisture depleted with 28.83 t/ha and the least was at 25% replacement of moisture depleted with 25.63 t/ha. However, with black polyethylene mulch, irrigation at 50% replacement of moisture depleted recorded significantly higher total yield with 57.39 t/ha followed by I_{75} with 41.09 t/ha then I_{100} with 28.21 t/ha and the least is I_{25} with 15.44 t/ha. Similarly, under no mulch condition, the highest yield was recorded at I_{50} with 23.35t/ha followed by I_{75} with 21.3 t/ha then I_{100} with 14.78 t/ha and the least was I_{25} with 7.29 t/ha. For the marketable yield, when irrigation was at I_{100} and I_{75} it was observed that mulching with either M_{RS} or M_{BP} resulted at significant higher yield than M_{NO}. However, when irrigation was at I_{50} the M_{BP} recorded the highest yield with 53.48 t/ha followed by M_{RS} with 36.21 t/ha and the least was M_{NO} with 19.56 t/ha. Irrigation at I_{25} gave the highest yield value of 22.28 t/ha with M_{RS} followed by M_{BP} with 11.50 t/ha and the least was M_{NO} with 4.74 t/ha. Base on different mulch materials,

mulching with M_{RS} resulted to higher yield at either irrigating at I_{75} or I_{50} followed by I_{100} with 25.72 t/ha and the least is I_{25} with 22.28 t/ha. When M_{BP} was adopted, the highest yield value was at I_{50} with 53.48 t/ha followed by I_{75} with 38.28 t/ha then I_{100} with 25.96 t/ha and the least was at I_{25} with 11.50 t/ha. With M_{NO}, the highest yield value was at I_{50} with 19.56 t/ha followed by I_{75} with 18.99 t/ha then I_{100} with 11.82 t/ha and the least was at I_{25} with 4.74 t/ha. The study showed that different irrigation levels and mulch type had effect on the total and marketable watermelon yield.

Table 4.1.1b Effect of Irrigation and mulch interaction on total and marketable yields of watermelon in Samaru during 2011/2012 dry season.

Total	Yield	(t/ha)		Marketable Yield (t/ha)		
Treatment	M_{RS}	M_{BP}	M_{NO}	M_{RS}	M_{BP}	M_{NO}
I_{100}	28.83d	28.21d	14.78g	25.72c	25.96c	11.82f
I_{75}	39.02c	41.09b	21.30f	36.15b	38.28b	18.99e
I_{50}	38.52c	57.39a	23.35f	36.21b	53.48a	19.56d
I_{25}	25.63e	15.44g	7.29h	22.28d	11.50f	4.74g
SE	0.454			0.946		

Means followed by the same letter(s), in a column of any treatment group are not significantly different at 5% level. ** = highly significant difference. Where I_{100}, I_{75}, I_{50} and I_{25} are 100%, 75%, 50% and 25% replacement of moisture depleted respectively. M_{RS}= rice straw mulch, M_{BP} = polythene mulch, M_{NO}= No mulch.

4.2 Irrigation Water Applied and Seasonal Water Use

Table 4.2a shows the effects of irrigation level and mulch type on irrigation water applied and seasonal water use by the crops. From the table it can be noticed that the

irrigation water applied and the seasonal water use decrease with increase in deficit irrigation. The pattern of decrease in water use as a result of deficit irrigation was expected since deficit irrigation reduces the amount of water available in the soil for plant to use. The highest irrigation water applied under irrigation treatment was at I_{100} with 371.72 mm followed by I_{75} with 274.42 mm then I_{50} with 230.67 mm and the least is at I_{25} with 168.37 mm. However, the seasonal water use was significantly higher at I_{100} with 271mm compared to the seasonal water use at I_{75} and I_{50} which are similar and I_{25} the least with 170.74 mm. In general, irrigation water applied and seasonal water use were found to decrease with decrease in % of moisture depletion replacement from 100% to 25%. However, with the use of different mulch materials, both the irrigation water applied and the seasonal water use recoded high value at M_{NO} with 308.65 mm and 293.55 mm, while M_{RS} and M_{BP} were found to be similar. Mulching with either rice straw or black polyethylene recorded significantly lower values of irrigation water and seasonal water use for watermelon compared to the no mulch treatment. This is expected as mulching helps to conserve moisture for crop use.

Table 4.2a Irrigation water applied and seasonal water use of watermelon as affected by irrigation and mulch in Samaru during 2011/2012 dry season.

Treatment	Irrigation water(mm)	Seasonal water use(mm)
Irrigation		
I_{100}	371.72a	271.83a
I_{75}	274.42b	216.30b
I_{50}	230.67c	213.11b
I_{25}	168.37d	170.74c
SE	5.6	8.95
CV	6.46	12.26
Significance	**	**
LSD	28.59	45.45
Mulching		
M_{RS}	239.85b	189.65b
M_{BP}	235.39b	173.03b
M_{NO}	308.65a	293.55a
SE	4.87	7.747
CV	6.46	12.26
Significance	**	**

Means followed by the same letter(s), in a column of any treatment group are not significantly different at 5% level. ** = highly significant difference. Where I_{100}, I_{75}, I_{50} and I_{25} are 100%, 75%, 50% and 25% replacement of moisture depleted respectively. M_{RS}= rice straw mulch, M_{BP} = polythene mulch, M_{NO}= No mulch.

When irrigation was fixed at either I_{100} or I_{25} the no mulch treatment recorded significantly higher irrigation water applied followed by M_{RS} then M_{BP} as shown in Table 4.2b. But when irrigation was at I_{75} and I_{50} the no mulch also recorded higher irrigation water applied followed by M_{BP} then M_{RS}. However for M_{RS}, M_{BP} and M_{NO} the highest water applied was at I_{100} followed by I_{75} then I_{50} and the least I_{25}. The highest irrigation water applied was at $I_{100}M_{NO}$ with 462.01 mm while the least is at I_{25} M_{BP} with 152.49 mm. Similarly, when irrigation was I_{100}, I_{75} and $I_{50,}$ M_{NO} recorded significant higher seasonal water use followed by M_{BP} then M_{RS}, but at I_{100} both the seasonal water use of M_{RS} and the M_{BP} are similar while at either I_{50} or I_{75} both M_{RS} and M_{BP} are similar. However seasonal water use of M_{NO} was highest followed by M_{BP} then M_{RS} when irrigation was given at I_{25}. When M_{RS} was adopted the highest seasonal water use was at I_{100} while I_{75}, I_{50} and I_{25} have similar seasonal water use. When with M_{BP} and $M_{NO,}$ the highest seasonal water use was at I_{100} followed by either I_{75} or I_{50} which are similar then the least is at I_{25}. The highest seasonal water use is at $I_{100}M_{NO}$ with 373.72mm while the least is at I_{25} M_{BP} with 119.65mm. The study revealed that deficit irrigation affect the irrigation water applied and seasonal water use irrespective of the mulch material applied. The interactions between deficit irrigation and mulch treatments in both irrigation water applied and seasonal water use of watermelon were found to be highly significant.

Table 4.2b Irrigation and mulch interaction on irrigation water applied and seasonal water use of watermelon in Samaru during 2011/2012 dry season.

	Irrigation Water Applied (mm)			Seasonal Water Use (mm)		
Irrigation	M_{RS}	M_{BP}	M_{NO}	M_{RS}	M_{BP}	M_{NO}
I_{100}	347.61b	305.55c	462.01a	246.78c	203.10c	373.72a
I_{75}	239.04e	268.86d	315.37c	173.81d	198.35d	276.70b
I_{50}	205.19f	214.65e	272.72d	169.60d	170.11d	299.60b
I_{25}	167.55g	152.49g	185.07f	168.41d	119.65e	224.17c
SE	9.75			15.49		

Means followed by the same letter(s), in a column of any treatment group are not significantly different at 5% level. ** = highly significant difference. Where I_{100}, I_{75}, I_{50} and I_{25} are 100%, 75%, 50% and 25% replacement of moisture depleted respectively. M_{RS}= rice straw mulch, M_{BP} = polythene mulch, M_{NO}= No mulch.

4.2.1 Crop water use efficiency (CWUE) and irrigation water use efficiency (IWUE)

Table 4.2.1a shows the highest CWUE under irrigation treatment at I_{50} with 218.05kg/ha/mm followed by I_{75} with 171.16kg/ha/mm then I_{25} with 105.61kg/ha-mm and the least at I_{100} with 98.33kg/ha-mm (but I_{25} and I_{100} are similar based on statistics). With different mulch material, the highest CWUE was obtained under M_{BP} with 205.78kg/ha-mm followed by M_{RS} with 180.94kg/ha/mm then the least under NM with 58.15kg/ha-mm. However, the highest IWUE was at I_{50} with180.83kg/ha-mm under irrigation treatment followed by I_{75} with 128.32kg/ha-mm then I_{25} with 97.83kg/ha-mm and the least is at I_{100} with 69.13kg/ha-mm. but by adopting different mulch materials the highest IWUE was

recorded by M_{BP} with 153.75kg/ha-mm followed by M_{RS} with 146.75kg/ha-mm and the least is at M_{NO} with 56.59kg/ha-mm.

Table 4.2.1a Crop water use efficiency and irrigation water use efficiency of watermelon as affected by irrigation and mulch in Samaru during 2011/2012 dry season.

Treatment	CWUE(kg/ha-mm)	IWUE(kg/ha-mm)
Irrigation		
I_{100}	98.33c	69.13d
I_{75}	171.16b	128.32b
I_{50}	218.05a	180.83a
I_{25}	105.61c	97.83c
SE	7.596	2.72
CV	15.36	6.85
Significance	**	**
LSD	28.59	45.45
Mulching		
M_{RS}	180.94b	146.75b
M_{BP}	205.78a	153.75a
M_{NO}	58.15c	56.59c
SE	6.58	2.35
CV	15.36	6.85
Significance	**	**

Means followed by the same letter(s), in a column of any treatment group are not significantly different at 5% level. ** = highly significant difference. Where I_{100}, I_{75}, I_{50}

and I_{25} are 100%, 75%, 50% and 25% replacement of moisture depleted respectively. M_{RS}= rice straw mulch, M_{BP} = polythene mulch, M_{NO}= No mulch.

Table 4.2.1b, shows the CWUE of M_{NO} significantly lower than that of either M_{BP} or M_{RS}, which were statistically similar when irrigation was given at I_{100}, and I_{25}. However, M_{BP} recorded higher CWUE followed by M_{RS} then M_{NO} when irrigation was given at I_{50}. When M_{RS} and M_{NO} were adopted I_{75} or I_{50} recorded higher CWUE than I_{25} or I_{100} which are similar. However, with M_{BP} the highest CWUE was at I_{50} followed by I_{75} then either I_{100} or I_{25} which are similar. The highest CWUE was at the treatment $I_{50}M_{BP}$ with 347.39kg/ha-mm and the least was at $I_{25}M_{NO}$ with 33.56kg/ha-mm. The highest CWUE of 347.39kg-ha obtained in this study is higher than 3.23kg/da-mm which was recorded by Yesim *et al.*, (2001) in Turkey. This higher value obtained in this research can be attributed to the black polyethylene mulch used.

When irrigation was at I_{100}, I_{50} and I_{25} the M_{BP} recorded significantly higher IWUE followed by M_{RS} then M_{NO}. But when the irrigation is at I_{75} the higher IWUE was at either M_{RS} or M_{BP} which are similar then M_{NO}. Adopting M_{RS}, the highest IWUE was at I_{50} followed by either I_{75} or I_{25} the I_{100}. However with M_{BP} and M_{NO} the highest IWUE were at I_{50} followed by I_{75} then either I_{100} or I_{25}. The highest IWUE was at I_{50} M_{BP} with 268.55kg/ha/mm and the least was at I_{100}NM. Similar relationships were also obtained in other studies (Srinivas *et al*., 1989; Senyigit, 1998).

Table 4.2.1b Irrigation and mulch interaction on CWUE and IWUE of watermelon in Samaru during 2011/2012 dry season.

CWUE (kg/ha-mm)				IWUE (kg/ha-mm)		
Irrigation	M_{RS}	M_{BP}	M_{NO}	M_{RS}	M_{BP}	M_{NO}
I_{100}	116.96c	138.41c	39.62e	82.95e	92.40d	32.05g
I_{75}	226.17b	207.53b	79.78d	163.33c	152.91c	68.74f
I_{50}	227.15b	347.39a	79.61d	187.77b	268.55a	86.16e
I_{25}	153.47c	129.80c	33.56e	152.94c	101.16d	39.41g
SE	13.156			4.71		

Means followed by the same letter(s), in a column of any treatment group are not significantly different at 5% level. ** = highly significant difference. Where I_{100}, I_{75}, I_{50} and I_{25} are 100%, 75%, 50% and 25% replacement of moisture depleted respectively. M_{RS}= rice straw mulch, M_{BP} = polythene mulch, M_{NO}= No mulch.

4.3 Yield Response Factor

The response factor (Ky) for the total growing season was 1.3895 for the no mulch treatment which agreed with the Ky values reported by Doorenbos and Kassam (1979), Erdem et al., (2003) and Mehmet and Kacira (2004) of 1.1, 1.27 and 1.15 respectively. However, variation could be observed due to lack of information in environmentally different conditions (Mehmet and Kacira 2004). The relationship of relative yield decrease to relative evapotranspiration deficit did not apply for the treatment with rice straw mulch and black polyethylene mulch, because with increase in deficit irrigation higher yield is obtained. So, there was no yield decrease for M_{RS} and M_{BP} with deficit irrigation. This may be due to the mulch involved in reducing evaporations.

Table 4.3 Relative yield decrease and relative evapotranspiration deficit of watermelon in Samaru during 2011/2012 dry season.

Treatment	Relative Et deficit	Relative yield decrease
$I_{100}M_{RS}$	0	0
$I_{75}M_{RS}$	0.295786	-0.35345
$I_{50}M_{RS}$	0.312804	-0.33611
$I_{25}M_{RS}$	0.317666	0.110995
$I_{100}M_{BP}$	0	0
$I_{75}M_{BP}$	0.027451	-0.45693
$I_{50}M_{BP}$	0.166176	-1.03438
$I_{25}M_{BP}$	0.413725	0.452676
$I_{100}M_{NO}$	0	0
$I_{75}M_{NO}$	0.259566	0.087794
$I_{50}M_{NO}$	0.198287	0.366595
$I_{25}M_{NO}$	0.400054	0.687794

Where I_{100}, I_{75}, I_{50} and I_{25} are 100%, 75%, 50% and 25% replacement of moisture depleted respectively. M_{RS}= rice straw mulch, M_{BP} = polythene mulch, M_{NO}= No mulch.

4.3.1 Crop coefficient

The Kc values for M_{RS} ranged from 0.33 - 0.42 for initial stage, 0.42 - 0.63 for development stage, 0.54 - 0.82 for mid season and 0.26 - 0.49 for late season. For M_{BP} the value ranges from 0.32 - 0.46 for initial stage, 0.51-0.69 for development stage, 0.53 - 0.69 for mid season and 0.29 - 0.44 for late season. For M_{NO} the value ranges from 0.40 -0.55 for initial stage, 0.64 -1.01 for development stage, 0.72 - 1.09 for mid season and 0.72 - 0.87 for late season. The Food and Agricultural Organization (FAO 2002) reported Kc estimate for different development stages of watermelon as 0.4 for initial stage, 0.4 -1.25

for development stage, 1.0 for mid stage and 0.75 late season stage which is in the range with the Kc values estimated in the research.

Table 4.3.1 Crop coefficient values for watermelon in Samaru during 2011/2012 dry season.

Treatment	IS	DS	MS	LS
	Kc of M_{Rs} Treatment			
$I_{100}M_{RS}$	0.42	0.63	0.82	0.46
	$Kc_{deficit}$ of M_{Rs} Treatment			
$I_{75}M_{RS}$	0.41	0.42	0.62	0.49
$I_{50}M_{RS}$	0.36	0.55	0.65	0.40
$I_{25}M_{RS}$	0.33	0.47	0.54	0.26
	kc of M_{BP} Treatment			
$I_{100}M_{BP}$	0.46	0.50	0.69	0.41
	$Kc_{deficit}$ of M_{BP} Treatment			
$I_{75}M_{BP}$	0.39	0.61	0.53	0.42
$I_{50}M_{BP}$	0.39	0.51	0.65	0.44
$I_{25}M_{BP}$	0.32	0.63	0.60	0.29
	kc of M_{NO} Treatment			
$I_{100}M_{NO}$	0.55	1.01	1.09	0.87
	$Kc_{deficit}$ of M_{NO} Treatment			
$I_{75}M_{NO}$	0.46	0.73	0.90	0.53
$I_{50}M_{NO}$	0.44	0.67	0.95	0.70
$I_{25}M_{NO}$	0.40	0.64	0.72	0.44

Where I_{100}, I_{75}, I_{50} and I_{25} are 100%, 75%, 50% and 25% replacement of moisture depleted respectively. M_{RS}= rice straw mulch, M_{BP} = polythene mulch, M_{NO}= No mulch.

From table 4.3.1, it can be noticed that crop coefficients were highly significantly affected by irrigation deficits, as the values decreased with the increase in deficit irrigation. The crop coefficient of the M_{NO} treatment was found to be the highest followed by that of M_{RS} and the least was that of M_{BP}. This might be attributed to high evaporation in M_{NO}, where there was less evaporation in M_{RS} and least evaporation in M_{BP} .

4.3.2 Water stress coefficients

Table 4.3.2 shows the water stress coefficient (K_s) and the seasonal average (SA) values computed. The Ks values of the four growth stages ranged from 0.59 to 1.00 across the treatments and seasons (Ks > 1.00 should be taken as 1.00), while the seasonal average Ks ranged from 0.65 to 0.98. Igbadun and Oiganji, (2012) reported that the Ks values generally range from zero (absolute water stress in which there is no evapotranspiration at all and the plant wilts) to 1.00 (no water stress in which evapotranspiration is at maximum). The water stress coefficients can be classified on the basis of its impact on seasonal consumptive use as: critical ($0.1 < Ks \leq 0.5$), severe ($0.51 < Ks \leq 0.75$), moderate ($0.76 < Ks \leq 0.90$) and minor ($0.91 < Ks \leq 0.99$) . Based on this classification, it could be inferred that using black polyethylene mulch the water stress coefficient is minor and moderate except for I_{25} which is severe at initial stage and late season stage, irrespective of irrigation level practiced. The seasonal average Ks of the I_{75} and I_{50} treatments were moderate using rice straw mulch and no mulch while that of I_{25} treatment was severe. However using black polyethylene mulch, seasonal average Ks for I_{75} and I_{50} treatments were minor while that of I_{25} treatment was moderate. This can be articulated that evaporation is low or zero with black polyethylene mulch.

Table 4.3.2 Water stress coefficient (K_s) for watermelon in Samaru during 2011/2012 dry season.

Treatment	IS	DS	MS	LS	SA
$I_{75}M_{RS}$	1.02**	0.67	0.75	1.09**	0.88
$I_{50}M_{RS}$	0.87	0.86	0.80	0.89	0.86
$I_{25}M_{RS}$	0.78	0.75	0.64	0.62	0.69
$I_{75}M_{BP}$	0.87	1.25**	0.77	1.03	0.98
$I_{50}M_{BP}$	0.83	1.07**	0.91	1.08	0.97
$I_{25}M_{BP}$	0.70	1.29**	0.84	0.73	0.89
$I_{75}M_{NO}$	0.86	0.73	0.84	0.67	0.77
$I_{50}M_{NO}$	0.81	0.66	0.87	0.83	0.79
$I_{25}M_{NO}$	0.74	0.63	0.65	0.59	0.65

Where IS = initial stage, DS = development stage, MS = mid season stage and LS = late season stage. **= $K_s > 1.0$ should be taken as 1.0. I_{100}, I_{75}, I_{50} and I_{25} are 100%, 75%, 50% and 25% replacement of moisture depleted respectively. M_{RS}= rice straw mulch, M_{BP} = polythene mulch, M_{NO}= No mulch.

4.3.3 Fruit Yield – Seasonal Crop Water Use

The fruit yield – seasonal crop water use relationship was established using the least square method. The line of best fit was drawn to establish linear relationship between fruit yield and seasonal crop water use for no mulch treatment. A linear relationship was found between the yield and seasonal crop water use as.

Fruit yield = 0.0949Eta – 11.177 ……4.1

From fig. 2, it reveals that an evapotranspiration threshold of 118.9 mm is required before fruit yield initiation.

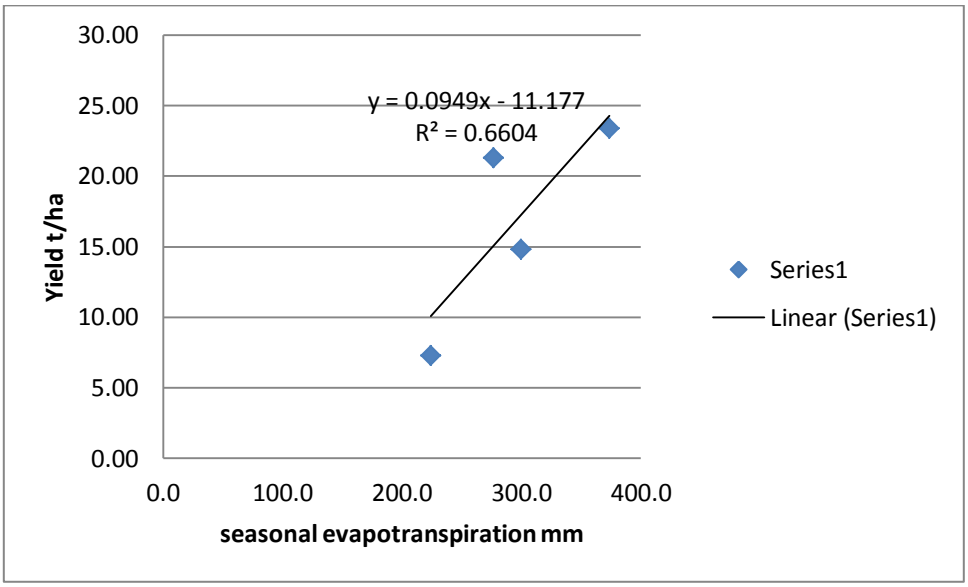


Fig. 2 fruit yield and seasonal crop water use relationship for No mulch.

Fig. 3 is the fruit yield of rice straw plotted against the seasonal evapotranspiration which gave the polynomial equation below with coefficient of regression (r^2) as 0.58.

Fruit yield = $-0.0262(Eta)^2 + 10.846Eta – 1054.3$ ……4.2

The seasonal evapotranspiration ranged from 180 mm to 260 mm and the fruit yield ranged from 69 t/ha to 25 t/ha.

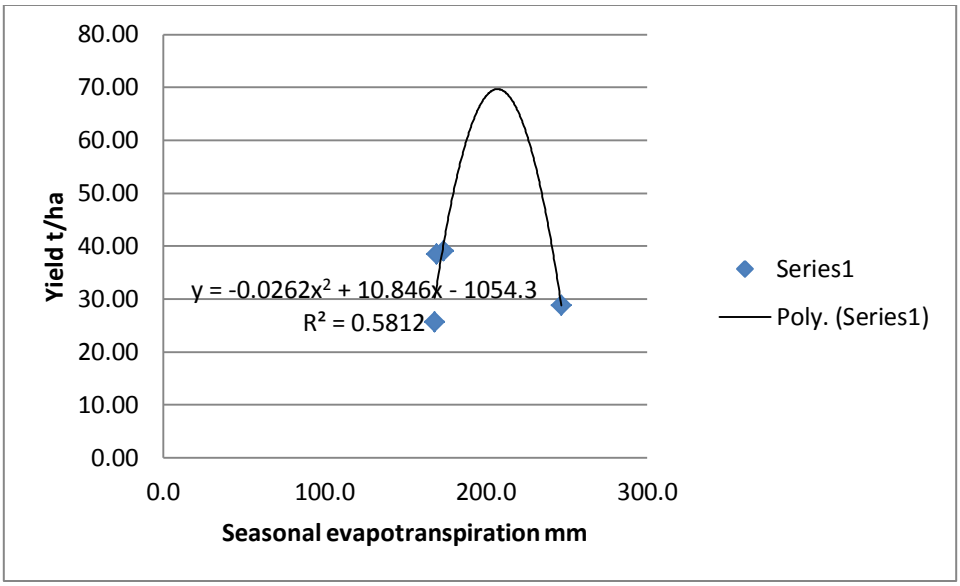


Fig. 3 fruit yield and seasonal crop water use relationship for Rice straw mulch

Fig. 4 is the fruit yield plotted against the seasonal evapotranspiration for black polyethylene mulch which gave a polynomial equation below with a coefficient of regression (r^2) as 0.99.

Fruit yield = $-0.0197(Eta)^2 + 60569Eta - 488.06$ ……4.3

The seasonal evapotranspiration for black polyethylene mulch ranged from 125 mm to 200 mm and the yield ranged from 15 t/ha to 58 t/ha. Seasonal evapotranspiration of 173 mm gave an optimum yield of 59 t/ha. The black polyethylene mulch gave the best yield as compared with the no mulch and rice straw mulch treatments which is order with what Soltani, *et al.*, reported as "plants under row covers (especially those made of polyethylene or polyester) grew faster, flowered sooner and yielded more fruit as a result of warmer temperature."

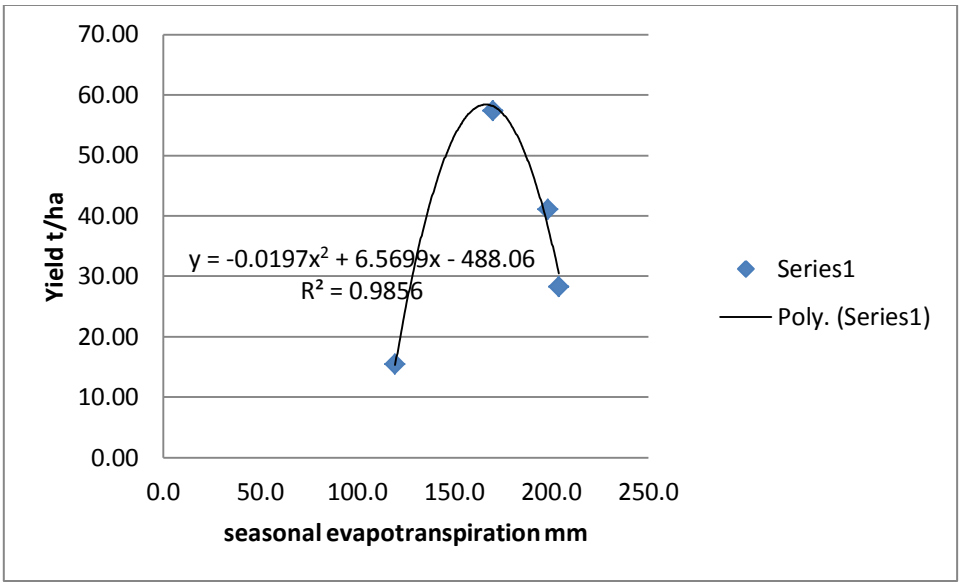


Fig. 4 fruit yield and seasonal crop water use relationship for black polyethylene mulch

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

A field experiment was conducted in 20011/2012 dry season at the Institute for Agricultural Research (I.A.R) farm, Samaru, Zaria. The experiment was used in determining the effects of irrigation levels and different mulch materials on fruit yield, crop water use and irrigation water applied. Other parameters obtained from the study was crop water use efficiency, irrigation water use efficiency, yield response factor and crop coefficient of watermelon crop grown under surface irrigation. The experiment was laid out in randomized complete block design (RCBD) with 12 treatment: consisting of four irrigation levels and three mulching material.

The maximum fruit yield was obtained when the watermelon crop was irrigated at irrigation at 50% replacement of moisture depleted and black polyethylene mulch ($I_{50}M_{BP)}$ with 57.39t/ha, while the lowest was at irrigation with 25% replacement of moisture depleted and no mulch ($I_{25}M_{NO}$) with 7.29t/ha. The maximum marketable yield is at $I_{50}M_{BP}$ with 53.48t/ha while the least is at $I_{25}M_{NO}$ with 4.7t/ha. The highest seasonal water use was obtained at $I_{100}M_{NO}$ with 373.72mm and the least is at $I_{25}M_{BP}$ with 119.65mm. The highest irrigation water applied is at $I_{100}M_{NO}$ with 462.01mm and the least is at $I_{25}M_{BP}$ with 152.49mm. The highest crop water use efficiency and irrigation water use efficiency is at $I_{50}M_{BP}$ with 347.39kg/ha-mm and 268.55kg/ha-mm respectively while the least was at

$I_{25}M_{NO}$ for crop water use efficiency with 33.56kg/ha-mm and at $I_{100}M_{NO}$ for irrigation water use efficiency with 32.09kg/ha-mm.

The Ky values obtained were 1.3895 for M_{NO}, and no relationship for M_{RS} and M_{BP}. The Kc values ranges from 0.42-0.55 for initial stage, 0.5-1.01 for development stage, 0.69-1.09 for mid season stage, 0.41-0.87 for late season stage.

5.2 Conclusion

The total yields for watermelon with M_{RS} were 28.55 t/ha, 40.35 t/ha, 38.83 t/ha and 26.49 t/ha with 100%, 75%, 50% and 25% replacement of moisture depleted, respectively. With M_{BP} the total yields were 28.8 t/ha,40.53t/ha, 58.49 t/ha and 17.15t/ha with 100%, 75%, 50% and 25% replacement of moisture depleted, respectively. And for treatment with M_{NO} the total yields were 14.94 t/ha, 21.33 t/ha, 23.38 t/ha and 7.38 t/ha with 100%, 75%, 50% and 25% replacement of moisture depleted, respectively. However, irrigating watermelon crop with application depth of 50% replacement of moisture depleted at each irrigation and mulching the field with black polyethylene mulch gave the highest fruit yield while irrigation with 25% replacement of moisture depleted and M_{NO} gave the least yield.

Moreover, irrigation at 50% replacement of moisture depleted with M_{BP} gave the highest CWUE and IWUE of 347.39kg/ha-mm and 268.55kg/ha-mm respectively while irrigation at 25% replacement of moisture depleted with M_{NO} gave the least CWUE of 33.56kg/ha-mm. And the least IWUE of 32.05kg/ha-mm was obtained from irrigation at 100% replacement of moisture depleted with M_{NO}. Use of black polyethylene mulch was

the best among others used in this research in terms of low irrigation water use and weed emergence.

The yield response factors of the watermelon for the total growing season were 1. 3895 for M_{NO}, and no relationship for M_{RS} and M_{BP}.

The Kc values ranges from 0.42-0.55 for initial stage, 0.5-1.01 for development stage, 0.69-1.09 for mid season stage, 0.41-0.87 for late season stage.

5.3 Recommendation

The following recommendation is presented for consideration of future work relating to different irrigation levels and different mulch materials.

1. It is recommended that values for seasonal evaporation and transpiration be determined separately so that proper relationship between seasonal transpiration and evapotranspiration can be established with seasonal water applied. Therefore, deep percolation can be calculated and also the aspect of soil temperature as affected by the polyethylene mulch should be incorporated.
2. Different crops and different varieties of watermelon should be used under different irrigation levels and different mulch materials to obtain the best combination of mulch and irrigation level without adverse effect on the crop yield.

3. In this research deficit irrigation was applied for the whole season with replacement of moisture depleted, for a more accurate approach the growth stages of watermelon crop should be subjected to the different levels of stress.

REFERENCES

Allen, R.G., Pereira, L.S; Raes, D. and Smith, M. (1998). Crop evapotranspiration: Guidelines for crop water requirements. FAO Irrigation and Drainage Paper56., 300pp.

Andrde-Junior, A. S., B. H. N. Rodrigues, C. Athayde- Sobrinho, F.B. Melo and E. A. Bastos,(1997). Yield and fruit quality in watermelon as affected by different irrigation levels. Horticulture. Brasileira, 15: 43-46.

Anons, (2006). *Nasarawa State Agricultural Development Programme,* Annual Crop Area and yield Survey (CAYS), Lafia, Nasarawa State. Unpublished survey report.

Bekele, S. and K. Tilahun. (2007). Regulated deficit irrigation scheduling of onion in semi arid region of Ethiopia. Agric Water Manage 89, 148-152.

Bucks, D. A., T. W. Sammis and G.L. Dickey. (1990). Irrigation for arid area. In Hoffman, G.J., Howell, T.A., and Solomon, K.H., (eds), *Management of Farm Irrigation Systems.* ASAE, St. Joseph.pp. 499-548.

Bungwon, Z.D., (1993). A Time-based stress-day index concept for irrigation scheduling. Unpublished M.Sc Thesis. Ahmadu Bello University, Zaria, Nigeria.

Chen Y. and J. Katan (1980). Effects of Solar heating of soils by transparent polyethylene mulching on their chemical properties. Soil science 130:271-277.

Clark, G.A. and D.N. Maynard, (1996). Vegetable production on various bed width using drip irrigation. Applied Eng. Agric., 8:28-32.

Clark, G.A., D.N. Maynard and C.D Stanley, (1996). Drip irrigation management for watermelon in a humid region. Amer. Soc. Agric. Eng., 12:335-340.

Doorenbos, J and Kassam, A.H (1979) Yield Response to water. FAO Irrigation and Drainage paper 33. Rome.

Doorenbos, J., Pruitt, W. O., (1977). Guideline for predicting crop water requirement, irrigation and Drainage, paper Vol.24,FAO,Rome.

El-Beheidi, M.A., A.A. Elsherbeiny and M.H. El-Sawah, (1990). Watermelon growth and yield as influenced by nutrition and irrigation methods in new reclaimed sandy soil, Egypt. J. Hort. 17:47-56.

English, M. and S. N. Raja (1996). Perspective on Deficit irrigation. Agric. Water Management 32:14.

Erdem, Y. and N. Yuksel, (2003). Yield response of watermelon to irrigation shortage. Scientia Horticulturae 98:365-383.

FAO, (2001). Statistics of horticultural crops. *faostat.fao.org/site/365/default.aspx.* Site visited on 5th Jan. 2013.

FAO, (2002). Deficit irrigation practices. Water Report No. 22, Rome.

FAOSTAT data (2004). FAO Statistical Database. Agriculture 4th March 2004. http://apps.fao.org/faostat/default.jsp. Site visited on 12th Sep. 2012.

FAO, . Cropwat. http:www.fao.org/nr/water/infores_database_cropwat.html. Site visited on 17th July 2012.

Flenet F., A. Bouniols, and C. Saraiva. (1996). Sunflower response to a range of soil moisture content. Euro J Agron 5:161-167.

Graham H.A.H., D.R. Decoteau, and D.E Linvill (1995). Development of a polyethylene mulch system that changes colour in the field. Hort. Sci., .30:265-9.

Harry, B.O. and Nyle, C.B. (1969). The nature and properties of soils. New York , Macmilian.

Hansen, V. E., O. W. Israelson and G. E. Stringham, (1979). Irrigation principle and practice. John Wiley and sons, Inc. New York. Pp. 417.

Hassan, M. J., (1996). Effect of soil moisture management and nitrogen levels on growth and yield of garlic. M.Sc Thesis, Department of Horticulture Bangladesh Agricultural University, Mymensingh Bangladash.

Howell T.A., R.H. Cuenca, K.H. Solomon (1990). Crop Yield Response. In: Management of Farm Irrigation Systems. ASAE, St. Joseph, MI. pp. 93-122.

Husaini, M.A., A.A. Ramalan and M.K. Othman, (2004). Soil moisture regime effect on the performance of watermelon under varying nitrogen levels in a semi – arid region. Journal of Applied Horticulture, 6 (2) : 72 – 75.

Ibragimov N., S.R. Evett, Y. Esanbekov, B.S. Kamilov, L. Mirzaev, J.P.A Lamers (2007). Water Use Efficiency for Irrigated Cotton in Uzbekistan under Drip and Furrow irrigation. Agric Water Manage 90:112-120.

Igbadun, H.E. and E. Oiganji. (2012). Crop coefficient and yield response factor of onion (Allium Cepa. L) under deficit irrigation and mulch practices in Samara, Nigeria. African Journal of Agricultural Research Vol. 7(36), pp. 5137-5152.

Igbadun, H.E (1997). Evaluation of selected crop yield, water use models for wheat crop. Unpublished Msc Thesis. Department of Agric. Engineering A.B.U Zaria.

Igbadun, H.E, A.S Bananda, K.P.R Andrew and F.M Henry (2008). Effects of Deficit Irrigation Scheduling on yields and soil water balance of irrigated maize. Irrig. Sci (2008) 27:11-23

Kadayifci A, G.I. Tuylu, Y. Ucar and B. Carmak. (2004). Effects of Mulch and Irrigation water amounts on lettuce's yield, evaporation, transpiration and soil evaporation in Isparta location, Turkey. Journal of biological sciences 4: (6) 751-755, 2004

Kirda, C. (2002). Deficit Irrigtion scheduling based on plant growth stages showing water stress tolerance in: Deficit Irrigation practice. Water reports 22. FAO, Rome, Pp1-3

Lee, S.G., J.S. lee., K.Y. Kym, J.H. Chung, S.O. Yoo and J.H. Bae, (1995). Effects of irrigation control on the quality and yield of watermelon (Citrullus Vullgaris) in high density staking cultivation under rain-shelter. RDA- J. Agric. Sci. Soil and Fertilizer, 37:245-249.

Mahdi A.,(2000). How to Evaluate Soil Moisture in the Field. Department of Agronomy Iowa State University, integrated Crop Management.

Mahrer Y., O. Naot, E. Rawtiz and J. Katan (1984). Temperature and Moisture Regimes In soil mulched with transperant polythene soil sci A.M. J., 48:362-367.

Majumdar, D.K. (2006). Irrigation water management; principles and practice. Practice Hall of India private limited pp 187.

Mehmet, S. and M. Kacira, (2004). The effect of drip irrigation regimes on watermelon [*citrullus lanatus* (Thunb.)] yield and yield component under semi-arid climatic conditions. Australian Journal of Agricultural Research. 55:1149-1157.

Micheal, A.M., (1978). Irrigation: Theory and Practice. Vikas publishing house Pvt.Ltd. New Delhi, India.

Mugalla C.I., C.M. Jolly and N.R. Martin (1996). Profitability of black plastic mulch for limited resources farmers. J.prod.Agric., 9:283-8

NAERLS (2010), Report of Agricultural Performance Survey. NAERLS, ABU, Zaria, Nigeria. Unpublished survey report.

Oiganji, E. (2010); Yield and soil water balance response of onions under mulch and deficit irrigation. Unpublished M.Sc Thesis, Dept. of Agricultural Engineering, ABU, Zaria, Nigeria.

Nerson, H., Y. burger and R. Berdugo, (1994). High plant density and irrigation increase watermelon yield grown for seed consumption. Adv. Hortic. Sci., 8: 101-105.

Oliveira, A.S., M.C.S. Leoa, L.G.R. Ferreira and H.G. Oliveira, (1992). Relationship between soil water deficit and flowering in watermelons. Hort.Brasilla, 10:80-82.

Panda, R.K., S. K. Behera and P.S. Kashyap. (2004). Effective management of irrigation Water for maize under stress conditions. Agricultural water management 66: 181 -203.

Pascale, S., G. Barbieri, C. Ruggyero and R. Munoz-Carpera, (1998). Consumptive water use and plant growth of watermelon as affected by irrigation and N- fertilization.

International symposium on water quality and quantity in Green house Horticulture, Tenerife, Canary island, Acta-Hort. 450:49-52.

Plauborg, F., M. N. Andersen, T. Heidmann and J. E. Olesen. (1996). MARKVAND: an irrigation scheduling system for use under limited irrigation capacity in a temperate humid climate. Irrigation theory and practice. Water reports 8. FAO-ICID-CIID, Rome. Pp. 177-184.

Prichard, T., B. Hanson, L. Schwankl, P. verdegaal and R. Smith. (2004). Deficit Irrigation of Quality wine grapes using micro-irrigation techniques. Publication of university of California Co-peration Extension, Department of Land, Air and Water resources, University of California, Davis, 5Pp.

Ramalan, A. A, C.U. Nwokeocha. (2000). Effects of furrow irrigation methods, mulching and soil water suction on the growth, yield and water use efficiency of tomato in the Nigerian savanna. Agricultural water management 45(2000) 317-330

Sam, G. and R. Dirk (2009). Deficit irrigation as an on- Farm strategy to maximize crop water management 96 (2009).

Senyigit, V., (1998). The effects of different irrigation methods doses and forms on the yield and quality of watermelon. Instytut Agronomique Mediterranean de Bari, master Thesis.

Seo, M.W., H.C. Rhee, Y.J. Kym, J.W. Lym, C.J. You and K.W. Park, (1997). Effects of irrigation amount on yield and sugar content of watermelon (citrullus Vulgaris S.) RDA, J. Hort. Sci., 39:30-34.

Smith, M., D. Kivumbi and L. K. Heng. (2002). Use of FAO CROPWAT model in deficit irrigation studies. Deficit irrigation practice. Water report. No. 22. Food and Agricultural Organisation of the United Nations, Rome. Pp. 17-28.

Soltani, N., Anderson, J.L. and Hamson, A.R (1995). Growth analysis of watermelon plants grown with mulches and rowcovers. *Journal of the American society for horticultural science* 120. Pp 1001-1009.

Srinivas, K., D.M. Hedge and G.V. Havanagi, (1989). Growth analysis of watermelon in relation to drip and furrow irrigation. Int. J. Agron., 34:222-227.

Stenizer E. (2004). Monitoring Soil Moisture Regimes of Field crops with Gypsum Blocks. Theoretical and Applied Climatology: Spring Wein, Vol 48, 2-3 Pp 159-165.

Stone, P. J., D. R. Wilson, J.B. Beid, R.N. Gillespie. (2001). Water Deficit effects on sweet corn water use, radiation use efficiency, growth and yield. J. Agri. Res 52: 103-113.

Stowell B., (2000). Organic kiwifruit production-maintaining soil fertility and yields. Kiwifruit, 139:18-21.

Wang, H. X, Zhang L, Dawes W.R, Liu C.M, (2001). Improving water use efficiency of irrigated crops in the North China plain measurement and modeling. Agric water manage 48:151-167

White I., S. J. Zegelin. (1994). Electric and Dielectric methods of monitoring water content. In: Vadose Characterisation and monitoring principles and cases studies.

Yesim, E., A.N. Yukse and A.H. Orta., (2001). The effects of deficit irrigation on watermelon yield, water use and quality characteristics. Paskitan journal of Biological science 4(7):785-789.

Zhang X, You M, Wang X. (1999). Effects of water deficits on winter wheat yield during its different development stages. Acta Agric boreali-sin 14:79-83.

Zhang, Y., Q. Yu, C. Liu, J. Jiang and X. Zhang. (2004). Estimation of winter wheat evapotranspiration under stress with semi- empirical approach. Agronomy journal, 96: 159-168.

Appendix I. Weather data for the 2012 irrigation cropping season.

Month	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Wind speed (km/day)	Sunshine hours	ETo (mm/day)
January	32.0	13.0	14	151	8.0	5.19
February	36.4	16.7	13	123	6.9	5.26
March	36.5	18.9	9	183	6.0	6.68
April	39.0	23.1	39	186	7.2	6.77
May	33.8	21.2	61	178	5.9	5.34

Appendix II. Physical properties of the soil at the experimental site.

Depth (cm)	**FC % @ 33 kPa**	**PWP % @ 1500 kPa**	**Bulk density (g/cm3)**	**Clay (%)**	**Silt (%)**	**Sand (%)**	**Textural class**
0 - 15	13.1	3.6	1.82	29	40	31	Loam
15 - 30	16.2	4.7	1.51	39	36	25	Clay Loam
30 - 45	17.6	5.1	1.56	41	30	29	Clay loam

Appendix III. Average water applied (mm) in weeks after planting

Treatment	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
$I_{100}M_{RS}$	40	40	40	19.4	21.9	22.2	29.2	32.2	30.2	18.9	14.2	12.5	10.3	347.8
$I_{100}M_{BP}$	40	40	40	13.2	18.4	18.3	25.9	29.1	19.8	18.8	10.2	12.2	10.2	305.0
$I_{100}M_{NO}$	40	40	40	32.1	35.1	34.1	43.5	36.0	34.3	34.3	29.1	29.3	11.2	462.8
$I_{75}M_{RS}$	40	40	40	11.4	11.2	8.7	19.1	19.9	10.7	10.3	14.7	7.3	7.5	240.9
$I_{75}M_{BP}$	40	40	40	11.3	18.0	16.9	16.2	12.4	13.3	11.1	9.2	9.0	7.1	268.3
$I_{75}M_{NO}$	40	40	40	13.4	19.2	22.3	24.4	24.9	21.5	20.9	12.0	12.4	7.5	315.5
$I_{50}M_{RS}$	40	40	40	6.6	7.8	13.0	14.5	15.1	7.0	7.4	6.4	4.7	5.0	205.5
$I_{50}M_{BP}$	40	40	40	8.5	5.8	11.1	14.8	14.1	10.6	10.5	9.7	4.5	5.2	214.8
$I_{50}M_{NO}$	40	40	40	19.9	10.1	13.4	13.5	19.0	13.2	19.8	12.1	11.1	5.1	272.3
$I_{25}M_{RS}$	40	40	40	3.4	4.1	4.4	7.7	7.4	6.2	3.9	4.9	2.7	2.6	167.2
$I_{25}M_{BP}$	40	40	40	4.3	4.0	7.5	6.7	7.2	3.7	2.7	1.8	1.8	2.3	152.9
$I_{25}M_{NO}$	40	40	40	4.1	8.4	6.6	9.8	7.4	7.7	6.3	4.0	4.2	2.6	185.1

Appendix IV. Average evapotranspiration mm in weeks after planting

Treatment	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
$I_{100}M_{RS}$	10	12	14	19	22	22	29	32	30	19	14	12	10	247
$I_{100}M_{BP}$	12	13	15	13	18	18	26	29	20	19	10	12	10	215
$I_{100}M_{NO}$	14	16	17	32	35	34	44	36	34	34	29	29	11	373
$I_{75}M_{RS}$	12	11	13	15	15	12	29	26	14	14	20	10	10	174
$I_{75}M_{BP}$	10	10	15	15	24	23	22	16	18	15	12	12	9	198
$I_{75}M_{NO}$	13	14	13	18	26	30	33	33	29	28	16	16	10	277
$I_{50}M_{RS}$	10	10	11	13	16	26	29	30	14	15	13	9	10	170
$I_{50}M_{BP}$	11	9	13	17	12	22	30	28	17	13	15	9	10	170
$I_{50}M_{NO}$	11	13	14	20	20	27	35	32	31	30	24	22	10	298
$I_{25}M_{RS}$	9	6	13	14	16	17	19	29	17	8	8	7	7	169
$I_{25}M_{BP}$	9	7	12	17	16	30	27	29	15	11	7	7	9	119
$I_{25}M_{NO}$	10	12	13	16	21	27	31	30	19	17	12	13	10	224

Appendix V. crop coefficient values in weeks after planting

Treatment	1	2	3	4	5	6	7	8	9	10	11	12	13
$I_{100}M_{RS}$	0.39	0.44	0.43	0.58	0.66	0.66	0.86	0.95	0.89	0.56	0.53	0.47	0.39
$I_{100}M_{BP}$	0.44	0.48	0.46	0.40	0.55	0.55	0.77	0.86	0.58	0.56	0.38	0.46	0.38
$I_{100}M_{NO}$	0.53	0.62	0.49	0.96	1.05	1.02	1.29	1.06	1.01	1.01	1.09	1.10	0.42
$I_{75}M_{RS}$	0.44	0.42	0.37	0.46	0.45	0.35	0.87	0.78	0.42	0.41	0.74	0.36	0.37
$I_{75}M_{BP}$	0.39	0.36	0.43	0.45	0.72	0.67	0.64	0.49	0.53	0.44	0.46	0.45	0.35
$I_{75}M_{NO}$	0.48	0.51	0.38	0.53	0.77	0.89	0.96	0.98	0.84	0.82	0.60	0.62	0.37
$I_{50}M_{RS}$	0.38	0.37	0.33	0.39	0.47	0.78	0.86	0.90	0.41	0.44	0.48	0.36	0.37
$I_{50}M_{BP}$	0.42	0.36	0.38	0.51	0.35	0.67	0.87	0.83	0.51	0.38	0.58	0.34	0.39
$I_{50}M_{NO}$	0.42	0.48	0.42	0.59	0.61	0.80	1.04	0.95	0.93	0.87	0.90	0.83	0.38
$I_{25}M_{RS}$	0.36	0.24	0.38	0.41	0.49	0.52	0.55	0.87	0.49	0.23	0.29	0.25	0.24
$I_{25}M_{BP}$	0.36	0.25	0.36	0.51	0.48	0.89	0.79	0.85	0.43	0.32	0.27	0.27	0.34
$I_{25}M_{NO}$	0.39	0.44	0.38	0.49	0.64	0.79	0.92	0.87	0.56	0.51	0.45	0.49	0.38

Appendix VI. Callibration curve for resistance block with gravimetric moisture content.

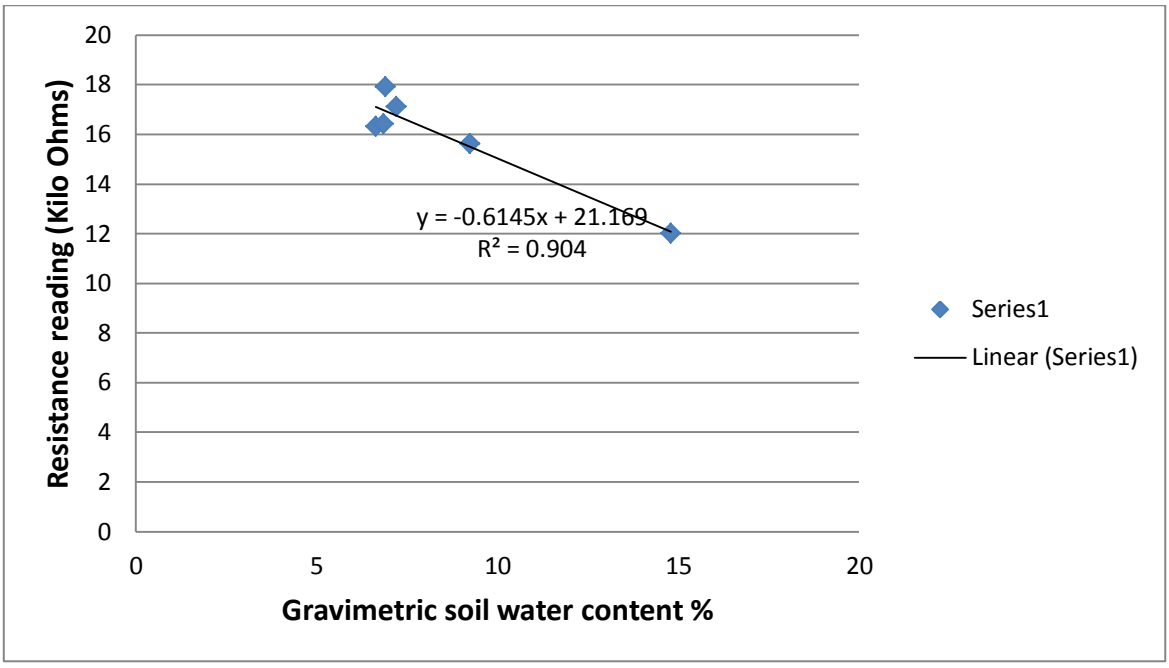


Fig. 5 . Callibration curve for resistance block with gravimetric moisture content.

Appendix VII. Sample moisture content obtained with resistance block.

Treatment	Rr @ Fc	Gm @ Fc	Rr @ Wp	Gm @ Wp
$I_{100}M_{RS}$	61.2	11.1016	66.7	10.19685
$I_{100}M_{BP}$	3.8	20.5439	4.9	20.36295
$I_{100}M_{NO}$	61.5	11.05225	83.3	7.46615
$I_{75}M_{RS}$	8.3	19.80365	14.5	18.78375
$I_{75}M_{BP}$	1.8	20.8729	2.5	20.75775
$I_{75}M_{NO}$	8.7	19.73785	9.5	19.60625
$I_{50}M_{RS}$	7.2	19.9846	8.5	19.77075
$I_{50}M_{BP}$	20.1	17.86255	37.7	14.96735
$I_{50}M_{NO}$	3.8	20.5439	4.8	20.3794
$I_{25}M_{RS}$	1.8	20.8729	2.9	20.69195
$I_{25}M_{BP}$	11.7	19.24435	12.7	19.07985
$I_{25}M_{NO}$	8.5	19.77075	9.8	19.5569

Where I_{100}, I_{75}, I_{50} and I_{25} are 100%, 75%, 50% and 25% replacement of moisture depleted respectively. M_{RS}= rice straw mulch, M_{BP} = polythene mulch, M_{NO}= No mulch. Rr = Resistance reading, Fc = Field capacity, Wp= Wilting point, and Gm= Gravimetric moisture content.



Plate 2: Watermelon plant mulched with Rice straw.



Plate 3: Watermelon plant mulched with Black polyethylene.