

**A STUDY OF THE EFFECT OF WATER STRESS ON YIELD,  
PHYSICO-CHEMICAL CHARACTERISTICS AND NUTRIENT  
UPTAKE OF *SOLANUM LYCOPERSICUM* L.**

**Oluwaseyi Motunrayo AKINRIMISI  
B.Sc. (Plant Biology)(Ilorin)  
(SCP13/14/H/2244)**

**A THESIS SUBMITTED TO THE DEPARTMENT OF BOTANY, FACULTY  
OF SCIENCE, OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, IN  
PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD  
OF THE DEGREE OF MASTER OF SCIENCE (M.Sc.) IN BOTANY**

**2016**

**OBAFEMI AWOLOWO UNIVERSITY**  
**HEZEKIAH OLUWASANMI LIBRARY**  
**POSTGRADUATE THESIS**

**AUTHORIZATION TO COPY**

**Author:** AKINRIMISI, Oluwaseyi Motunrayo  
**Title:** A Study of the Effect of Water Stress on Yield, Physico-chemical Characteristics and Nutrient Uptake of *Solanum lycopersicum* L.  
**Degree:** M.Sc.  
**Year:** 2016

I, Akinrimisi O.M., hereby authorize the Hezekiah Oluwasanmi Library to copy my thesis, in whole or in part, in response to request from individual researchers or organizations for the purpose of private study of research.

.....

.....

**Signature**

**Date**

## CERTIFICATION

This is to certify that this study was carried out by AKINRIMISIOluwaseyi Motunrayo, SCP13/14/H/2244, as part of the requirements for the award of Master of ScienceDegree in Botany of the Obafemi Awolowo University, Ile-Ife, Nigeria.

Prof. A.A. Adelusi

-----

**Supervisor**

-----

**Signature**

-----

**Date**

Dr. A.E. Folorunso  
-----  
**Head of Department**

-----  
**Signature**

-----  
**Date**

## DEDICATION

This is dedicated to the Almighty God, the keeper of my dreams and lifter up of my head. The one who has given me the infinite opportunity to successfully carry out this research work, and also to my Gold and Jewel; Pastor and Mrs E.A. Akinrimisi to have laid the solid foundation for my education.

OBAFEMI AWOLowo UNIVERSITY

## ACKNOWLEDGEMENT

My profound, gratitude goes to the Lord of Host, the God Almighty for His immeasurable Love, Grace and Favour that I have enjoyed every day of my life.

To my parents, Pastor and Mrs. Akinrimisi who shouldered the responsibilities of my academic demands, most especially to my mother an uncommon Matriach with a high sense of moral rectitude, your unequivocal stand in the gap and characteristics mien can never be quantified in numerical terms, I remained indebted to you both forever. Thank you so much.

My sincere appreciation goes to my supervisor, Prof A. A. Adelusì for his genuine and conscientious effort under his tutelage as a neophyte in academics. This research would not have been completed but for his persistent drive and push at every stage of this work. I am indeed very grateful.

I owe all my lecturers in and outside the Department an avalanche of appreciations. Dr A. E. Folorunso (HOD), Professors S. O. Oke, H. C. Illoh, J.O. Faluyi, J.I. Muoghalu, A.O. Isichei, Adedeji, Drs. F.A. Oloyede, A.I. Odiwe, S.A. Saheed, Oladipo, A. M. A. Sakpere, A. M. Makinde, for his plethora of advice during the course of this study. I also thank Dr. (Mrs) O.O Arogundade, Mrs. A.O. Bolaji, Mr. and Mrs. A.Z. Ogbimi. I am also grateful for the technical support of the non-teaching staff of the Department. My appreciation is not complete without acknowledging the effort of Dr. R.O. Akinwale for his advice and mentoring that has brought about a successful completion of this research work. May God shower his mercy and favour upon them all.

Special thanks to my fiancé, Mr. Abiola Oluwadamilare a friend, humility personified, a study in consummate integrity and self-effacement, an astute administrator with uncommon wits and intimidating credentials for his love, care and words of advice throughout the period of this work.

Sincere appreciation goes to my lovely and dependable siblings for their constant financial support, tender care and love. They have been wonderful. My love bubbles for them.

Big appreciation to my colleagues under the same supervisor; Olowolaju Ezekiel and Adiatu Abiodun for their support. To my friends, Kolawole Bukola, Ariyo Damilola, Opoola Toluwase, Akinboluji Remilekun, you guys are the best. Also, to every other person who contributed to this work at one point or the other during the course of the research.

Finally, to all those that nurtured me from the broken pieces of my past to build an edifice of hope in the intellectual firmament. Thanks and God bless.

OBAFEMI AWOLowo UNIVERSITY

## TABLE OF CONTENTS

Content	Page
Title	i
Authorization	ii
Certification	iii
Dedication	2
Acknowledgement	3
Table of Contents	5
List of Tables	9
List of Figures	10
Abstract	<b>Error! Bookmark not defined.</b>
<b>CHAPTER ONE: INTRODUCTION</b>	<b>Error! Bookmark not defined.</b>
1.1 Stress in Plant	<b>Error! Bookmark not defined.</b>
1.2 Tomato ( <i>Solanum lycopersicum</i> )	2
1.3 Modern Day Uses and Nutritional Values	3
1.4 Justification of the Study	<b>Error! Bookmark not defined.</b>
1.5 Objectives of this Study	<b>Error! Bookmark not defined.</b>
1.6 Contribution to Knowledge	<b>Error! Bookmark not defined.</b>
<b>CHAPTER TWO: LITERATURE REVIEW</b>	<b>Error! Bookmark not defined.</b>
2.1 Effect of Drought on Photosynthesis	<b>Error! Bookmark not defined.</b>



2.2 Osmotic Adjustment Mechanisms of Plants to Water Stress **Error! Bookmark not defined.**

2.3 The Relative Water Content and Drought **Error! Bookmark not defined.**

2.4 Drought and Nutrient Uptake **Error! Bookmark not defined.**

2.5 Adaptation to Drought **Error! Bookmark not defined.**

2.5.1 Drought Escape

**Error! Bookmark not defined.**

2.5.2 Dehydration Avoidance

**Error! Bookmark not defined.**

2.5.3 Dehydration

Tolerance

**Error! Bookmark not defined.**

**CHAPTER THREE: MATERIALS AND METHODS** **Error! Bookmark not defined.**

3.1 Experimental Seeds **Error! Bookmark not defined.**

3.2 Collection of Soil **Error! Bookmark not defined.**

3.3 Preliminary Analysis of the Soil Samples **Error! Bookmark not defined.**

3.4 Screenhouse Experiment **Error! Bookmark not defined.**

3.5 Raising of Seedlings **Error! Bookmark not defined.**

3.6 Experimental Layout **Error! Bookmark not defined.**

3.7 Experimental Design **Error! Bookmark not defined.**

3.8 Application and Quantification of the Levels of Stress **Error! Bookmark not defined.**

3.9 Measurement of Morphological Parameters **Error! Bookmark not defined.**

- 3.10 Yield Components **Error! Bookmark not defined.**
- 3.11 Relative Water Content (RWC) **Error! Bookmark not defined.**
- 3.12 Determination of Physico-chemical Characteristics of the Tomato Fruits **Error!**  
**Bookmark not defined.**
- 3.12.1 Determination of Total Soluble Solids  
**Error! Bookmark not defined.**
- 3.12.2 Determination of Titratable Acidity  
**Error! Bookmark not defined.**
- 3.12.3 Determination of Dry Matter Content  
**Error! Bookmark not defined.**
- 3.13 Proximate Composition of the Tomato Fruits **Error! Bookmark not defined.**
- 3.13.1 Determination of Crude Protein  
**Error! Bookmark not defined.**
- 3.13.2 Determination of Crude Fat  
**Error! Bookmark not defined.**
- 3.13.3 Determination of Crude Fibre  
**Error! Bookmark not defined.**
- 3.13.4 Determination of Moisture Content  
**Error! Bookmark not defined.**
- 3.13.5 Determination of Total Ash  
**Error! Bookmark not defined.**
- 3.13.6 Determination of Carbohydrate Content  
**Error! Bookmark not defined.**
- 3.14 Proline Content of the Leaves **Error! Bookmark not defined.**

3.15 Mineral Nutrient of Samples **Error! Bookmark not defined.**

3.15.1 Digestion Procedure for Samples

**Error! Bookmark not defined.**

3.15.2 Determination of Sodium, Potassium, Magnesium, Calcium and Manganese by Atomic Absorption Spectrometry

**Error! Bookmark not defined.**

3.16 Statistical Analysis **Error! Bookmark not defined.**

## CHAPTER FOUR: RESULTS **Error! Bookmark not defined.**

4.1 Soil Analysis **Error! Bookmark not defined.**

4.2 Effect of Different Regimes of Watering treatment on the Morphological Parameters of Six Tomato Varieties. **Error! Bookmark not defined.**

4.2.1 Shoot Height

**Error! Bookmark not defined.**

4.2.2 Number of Leaves

**Error! Bookmark not defined.**

4.2.3 Leaf Area

**Error! Bookmark not defined.**

4.2.4 Number of Branches

**Error! Bookmark not defined.**

4.2.5 Bud Number

**Error! Bookmark not defined.**

4.2.6 Plant Height

**Error! Bookmark not defined.**

4.2.6 Stem Diameter

**Error! Bookmark not defined.**

4.2.7 Root Length

**Error! Bookmark not defined.**

4.2.8 Shoot and Root Fresh Weight

**Error! Bookmark not defined.**

4.2.9 Shoot and Root Dry Weight

**Error! Bookmark not defined.**

4.3.1 Flower Number

**Error! Bookmark not defined.**

4.3.2 Fruit Number

**Error! Bookmark not defined.**

4.3.3 Fruit Diameter and Length

**Error! Bookmark not defined.**

4.4.4 Fruit Fresh and Dry Weight

**Error! Bookmark not defined.**

4.4 The Effect of Osmotic Adjustment and Physiological Responses of the Six Tomato Varieties under Different Watering regimes. **Error! Bookmark not defined.**

4.4.1 Relative Water Content (RWC)

**Error! Bookmark not defined.**

4.4.2 Proline Content

**Error! Bookmark not defined.**

4.5 Physico-Chemical Properties of the Six Tomato Varieties at Different Watering regimes. **Error! Bookmark not defined.**

**Error! Bookmark not defined.**

**CHAPTER 5: DISCUSSION**

**Error! Bookmark not defined.**

5.1 Morphological Parameters

**Error! Bookmark not defined.**

5.2 Osmotic Adjustment and Physiological Response

**Error! Bookmark not defined.**

5.3 Nutrient Uptake and Water Stress Response

**Error! Bookmark not defined.**

 5.4 Yield and Yield Components Responses to Water Stress  
**Error! Bookmark not defined.**

**Bookmark not defined.**

 5.5 Physico-chemical Properties Response to Water Stress  
**Error! Bookmark not defined.**

**Bookmark not defined.**

**CONCLUSION AND RECOMMENDATION**

**Error! Bookmark not defined.**

**REFERENCES**

**Error! Bookmark not defined.**

**APPENDICES**

**Error! Bookmark not defined.**

**LIST OF TABLES**

<b>Table</b>	<b>Page</b>
1. Chemical and Physical Properties of the Experimental Soil.	<b>Error! Bookmark not defined.</b>
2. Effects of Watering regimes and Varieties on Morphological Traits of Tomato	<b>Error! Bookmark not defined.</b>
3. Yield And Yield Components of Tomato Varieties Evaluated at the Screenhouse under Different Watering regimes.	<b>Error! Bookmark not defined.</b>
4. Effects of Watering regimes and Varieties on Osmotic Adjustment and Physiological Responses of Tomato Varieties.	<b>Error! Bookmark not defined.</b>
5. Physico-Chemical and Proximate Composition of the Six Tomato Varieties under Different Watering regimes.	<b>Error! Bookmark not defined.</b>

6. Mineral Nutrient Composition of the Six Tomato Varieties under Different Watering regimes. **Error! Bookmark not defined.**

#### LIST OF FIGURES

Figure	Page
1a-c Shoot Height of Tomato Varieties under the Different Watering regimes Evaluated in the Screenhouse.	<b>Error! Bookmark not defined.</b>
1d-f Shoot Height of Tomato Varieties under the Different Watering regimes Evaluated in the Screenhouse.	<b>Error! Bookmark not defined.</b>
2a-c Number of Leaves of Tomato Varieties under the Different Watering regimes Evaluated in the Screenhouse.	<b>Error! Bookmark not defined.</b>

- 2d-f Number of Leaves of Tomato Varieties under the Different Watering regimes Evaluated in the Screenhouse. **Error! Bookmark not defined.**
- 3a-c Leaf Area (cm<sup>2</sup>) of Tomato Varieties under the Different Watering regimes Evaluated in the Screenhouse. **Error! Bookmark not defined.**
- 3d-f Leaf Area (cm<sup>2</sup>) of Tomato Varieties under the Different Watering regimes Evaluated in the Screenhouse. **Error! Bookmark not defined.**
- 4a-c Branch Number of Tomato Varieties under the Different Watering regimes Evaluated in the Screenhouse. **Error! Bookmark not defined.**
- 4d-f Branch Number of Tomato Varieties under the Different Watering regimes Evaluated in the Screenhouse. **Error! Bookmark not defined.**
- 5a-c Bud Number of Tomato Varieties under the Different Watering regimes Evaluated in the Screenhouse. **Error! Bookmark not defined.**
- 5d-f Bud Number of Tomato Varieties under the Different Watering regimes Evaluated in the Screenhouse. **Error! Bookmark not defined.**
- 6a-c Flower Number of Tomato Varieties under the Different Watering regimes Evaluated in the Screenhouse. **Error! Bookmark not defined.**
- 6d-f Flower Number of Tomato Varieties under the Different Watering regimes Evaluated in the Screenhouse. **Error! Bookmark not defined.**
- 7a-c Fruit Number of Tomato Varieties under the Different Watering regimes Evaluated in the Screenhouse. **Error! Bookmark not defined.**
- 7d-f Fruit Number of Tomato Varieties under the Different Watering regimes Evaluated in the Screenhouse. **Error! Bookmark not defined.**

## ABSTRACT

This study investigated the osmotic adjustment and nutrient uptake of six varieties of tomato (*Solanum lycopersicum* L.) at different watering regimes and evaluated the relationship between water stress and marketable yield of the tomato varieties. This was with a view to determining the role of water in crop growth and production.

The six varieties of *Solanum lycopersicum* used for the study were: Chico III, Ibadan local, Ibarapa, Ife-1, Rio Grande and Roma-VF were the tomato varieties collected from the National Horticultural Research Institute (NIHORT), Ibadan, Oyo State, Nigeria. The tomato seed varieties were sown in bowls of 54 cm x 8 cm dimension and the seedlings were transplanted after 21 days of establishment into 54 experimental pots (20 cm x 21 cm) at the rate of three seedlings per pot. The seedlings were raised in a screenhouse under normal environmental conditions. The experimental layout was quantified with three levels of watering regimes ( $W_1$ ,  $W_3$  and  $W_5$ ). A 6 x 3 factorial experiment laid out in a completely randomised design (CRD) was used; with watering regimes and varieties as the factors. Samplings were carried out after three weeks of transplanting. Data were recorded for growth, yield and yield components. The parameters studied for osmotic adjustment were relative water content (%) and proline ( $\mu\text{molg}^{-1}$ ). Sodium, potassium, magnesium, calcium and manganese contents were analysed after digestion using Perkin Elmer Analyst Model – 400 Atomic Absorption Spectrophotometer. The proximate composition and the physico-chemical properties of the tomato varieties were carried out using standard procedures. Data were subjected to analysis of variance (ANOVA) while the means were separated using least significant difference (LSD) post-hoc at  $p \geq 0.05$  level of probability.



Tomato plants subjected to water stress were reduced significantly ( $p \geq 0.05$ ) in their shoot height, number of leaves and plant biomass compared to those that were watered everyday. Accumulation of proline enhanced water stress tolerance in tomato varieties of Ibadan local and Ibarapa, by improving the osmotic adjustment of the varieties, while the high relative water content in the Chico III and Roma-VF varieties made them more drought tolerant. The highest uptake of sodium, magnesium, calcium and manganese were enhanced by drought condition in Ife-1, Ibarapa and Roma-VF varieties, while, the highest uptake of potassium was influenced by watering everyday. Better fruit yield was obtained with three days watering regime. However, 35 % and 104 % reduction in yield respectively occurred with watering everyday and watering every five days. Tomato plants watered every five days had the best accumulated levels of proteins, carbohydrate and dry matter, while the plants watered every three days had the best moisture, fat and ash contents. A considerable range of variation was recorded among the tomato varieties and the drought tolerance of the varieties were in the order: Ife-1 = Chico III > Ibadan local = Roma-VF > Rio Grande > Ibarapa.

The study concluded that the accumulation of proline could not be used as the sole determinant of osmotic adjustment in water stressed plant but also potassium and magnesium ions uptake.

## CHAPTER ONE

### INTRODUCTION

#### 1.1 Background to the Study

##### Stress in Plant

Stress in plants can be defined as any external factor that negatively influences plant growth, productivity, reproductive capacity or survival (Rhodes and Nadolska-Orczyk, 2001). This includes a wide range of factors which can be broadly divided into two main categories: abiotic or environmental stress factors, and biotic or biological stress factors. Stress is also defined according to Grime (1979) as the external constraints which limit the dry matter production of vegetation. Stress potentially is responsible for the abnormalities often discovered in plants which brought about favourable and unfavourable conditions. These stresses include abiotic or environmental stress factors such as salt and ion stress, heat stress, radiation stress, flooding, drought, low and high temperature and heavy metal toxicity. Stress may also be biotic or biological stress such as diseases and competition stress.

Organisms need to adapt themselves to changes in fluctuating environmental conditions. The plants, since they are not able to escape from adverse environmental conditions, have to rely entirely on their developmental plasticity to survive (Krouk *et al.*, 2011). These adaptations include the responses to temperature fluctuations, water and nutrients imbalance, UV radiation, pathogens, and insects, among other biotic and abiotic stresses. Plant growth regulators (phytohormones), compounds derived from plant biosynthetic pathways, mediate these responses by acting either at the site of synthesis or following their transport, elsewhere in the

plant. Collectively, plant hormones regulate every aspect of plant growth, development and the responses of plants to biotic and abiotic stresses (Peleg and Blumwald, 2011).

A key adaptive mechanism in many plants grown under abiotic stresses, including salinity, water deficit and extreme temperatures, is accumulation of certain organic compounds of low molecular mass, generally referred to as compatible osmolytes (Hare *et al.*, 1998; Sakamoto and Murata, 2002). Under stress, different plant species may accumulate a variety of osmolytes such as sugars and sugar alcohols (polyols), proline, tertiary and quaternary ammonium compounds, and tertiary sulphonium compounds (Sairam and Tyagi, 2004).

## 1.2 Tomato (*Solanum lycopersicum*)

In 1753, the tomato was placed in the genus *Solanum* by Linnaeus as *Solanum lycopersicum* L. (derivation, 'lyco', wolf, plus 'persicum', peach, i.e., "wolf-peach"). However, in 1768, Philip Miller placed it in its own genus, and he named it *Lycopersicon esculentum* (Slow food Upstate, 2014). This name came into wide use, but was in breach of the plant naming rules (Slow food Upstate, 2014). Technically the combination *Lycopersicon lycopersicum* (L.) H. Karst, would be correct, but this name (published in 1881) has hardly ever been used. Therefore it was decided to conserve the well-known *Lycopersicon esculentum*, making this the correct name for the tomato when it is placed in the genus *Lycopersicon*. However, genetic evidence (e.g. Peralta and Spooner, 2001; Foolad, 2007) has now shown that Linnaeus was correct in the placement of the tomato in the genus *Solanum*, making the Linnaean name correct; if *Lycopersicon* is excluded from *Solanum*, *Solanum* is left as a paraphyletic taxon. Despite this, it is likely that the exact taxonomic placement of the tomato will be controversial for some time to come, with both names found in the literature.

Botanically speaking a tomato is the ovary, together with its seeds, of a flowering plant, i.e. a fruit. However, from a culinary perspective the tomato is typically served as a meal, or part of a main course of a meal, meaning that it would be considered a vegetable (a culinary term which has no botanical meaning), (Slow food Upstate, 2014).

The tomato (*Solanum lycopersicum*) is a short-lived perennial plant, grown as an annual plant, in the Solanaceae or nightshade family ([Slow Food® Upstate](#), 2014; Solanaceae Source), typically growing to 1-3 m tall, with a weakly woody stem that usually scrambles over other plants. The fruit is an edible, brightly coloured (usually red, from the pigment lycopene) berry, 1-2 cm diameter in wild plants, commonly much larger in cultivated forms. Though it is botanically a berry, a subset of fruit, the tomato is nutritionally categorized as a vegetable ([Enza Zaden – Teelnieuws, 2009](#); [Tomaat September, 2010](#)).

The Tomato is native to South America but growing in temperate climates worldwide. The tomato begins its colourful and varied history upon the coastal highlands of western South America, where it was being enjoyed by the native peoples for a long time. Evidence supports the theory that from Peru it found its way to Central America where it was domesticated as a little yellow fruit, called '*xitomatl*', meaning "plump thing with a navel", and later called '*tomatl*' by other Mesoamerican peoples ([Tomato History](#), 2013). Maya and other peoples in the region used the fruit in their cooking, and it was being cultivated in southern Mexico, and probably in other areas, by the 16th Century.

### 1.3 Modern Day Uses and Nutritional Values

The tomato's medicinal properties had already been endorsed in Continental Europe in the 16<sup>th</sup> Century and their consumption was believed to benefit the heart among other things, as it contains lycopene, one of the most powerful natural antioxidants which, especially when

cooked, has been found to help prevent prostate, lung, stomach, pancreatic, colorectal, oesophageal, oral, breast and cervical cancers ([Slow Food® Upstate](#), 2014).

For more information, please contact [ir-help@oauife.edu.ng](mailto:ir-help@oauife.edu.ng)

OBAFEMI AWOLOWO UNIVERSITY