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DETERMINING PROPER IRRIGATION METHOD AND SCHEDULE IN MAIZE PRODUCTION FOR SEMI-ARID ENVIRONMENT IN NIGERIA

ALI UMAR BASHIR

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By

ALI UMAR BASHIR

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

This thesis is dedicated to my late father Alkali Umar Goni Bashir, My mother Fatime Musa and my lovely children.

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

DETERMINING THE PROPER IRRIGATION METHOD AND SCHEDULE IN MAIZE PRODUCTION FOR SEMI-ARID ENVIRONMENT OF NIGERIA

By

ALI UMAR BASHIR

December 2017

Chairman : MD. Rowshon Kamal, PhD
Faculty : Engineering

Water scarcity due to the impact of climate change and the increasing global demand for water from many sectors including agriculture, has become a global concern especially in semi-arid regions where irrigation is the only alternative for crop production to meet the demand for food for the rapidly growing population. Maize production in the semi-arid region of Nigeria relies widely on irrigation. This is due to the extremely irregular rainfall, to the extent that the amount and distribution in space and time had not been ideal to optimally support crop production adequately. Farmers in the region use furrow irrigation method and fixed irrigation interval schedule for maize production. The irrigation method and schedule used by the farmers has become unsustainable due to low yield, low water use efficiency, low quality of maize kernels and low net farm income. Thus, there is a growing gap between the demand for maize and its production to meet the food requirement for the growing population in the region. The aim of this study was to determine the proper irrigation method and schedule in maize production for semi-arid environmental of Nigeria. Two field experiments were conducted in the 2014 and 2015 seasons at the Teaching and Research Farm of Ramat Polytechnic Maiduguri, Borno State which is located in the semi-arid region of Northern Nigeria. The experiments consisted of a factorial combination of irrigation methods and scheduling methods laid in a randomized complete block design that resulted in nine (9) treatments. Irrigation methods were at 3 levels namely; drip, sprinkler and furrow irrigation methods. Irrigation scheduling methods were also at three levels namely fixed irrigation interval (7days), soil moisture based schedule using tensiometer at trigger level of 30 cbar and climate based schedule based on the ratio of irrigation amount to cumulative pan evaporation of 1 (1.0 IW/CPE). The treatments were randomly assigned to plots and replicated 3 times. A total of 27 experimental plots were used for the study. Samples of water were taken from the source of water (tube wells) used for the irrigation of the maize crop and analyzed to ascertain its

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suitability or otherwise for irrigation. The samples were analysed for physicochemical properties using the procedures recommended in the standard methods for the examination of water and waste water and the values of total dissolved solids, sodium adsorption ratio, magnesium adsorption ratio, residual sodium carbonate and Kelly ratio were calculated. Growth, yield and yield parameters that were recorded during the crop growth and development were subjected to Analysis of Variance (ANOVA) to determine the effect of irrigation methods and irrigation schedules on the growth, yield and yield components of maize using Statistical Analysis System (SAS 9.4) software. Duncan multiple range test (DMRT) at $P \leq 0.05$ was used to compare significantly different means and their interactions. Correlation analysis was performed to determine the relationship between growth and yield parameters with yield. The crop water use and irrigation water use efficiencies, maize kernel quality, the performance of irrigation systems used in terms of uniformity of water distribution, water savings and their irrigation efficiencies were evaluated. The economic viability of maize production under the different irrigation and scheduling methods were determined. The result of the water quality analysis revealed that the source of water in the study area is free from salinity, permeability and toxicity problems and is suitable for irrigation usage. . The result of the study revealed that the growth, yield and yield parameters were significantly affected by irrigation methods and schedules in both growing seasons with better performance from drip compared to sprinkler and furrow irrigation methods. The result also shows that maize performed better under sprinkler compared to furrow irrigation method. The result further revealed that, plots scheduled using tensiometer and the ratio of irrigation amount to cumulative pan evaporation methods that resulted in 4days irrigation interval performed better compared to the fixed interval (7 days). The highest values of crop water use and irrigation water use efficiencies of 0.92 and 0.73 kg/m^3 respectively were obtained from drip irrigated plots scheduled with tensiometer compared to 0.73 and 0.56 kg/m^3 for sprinkler and 0.66 and 0.41 kg/m^3 for furrow. The result further showed that the use of drip irrigation method has resulted in water savings of 17.31% and 31.75% when compared with sprinkler and furrow irrigation methods respectively. The uniformity of water distribution was higher in drip irrigation method with emission uniformity of 91.2% compared to sprinkler with a coefficient of uniformity of 75% and furrow with distribution uniformity of 75%.The irrigation efficiencies of the drip, sprinkler and furrow irrigation methods used were 80%, 76% and 64% respectively. The result on the effect of irrigation methods and schedules on the quality of maize showed that maize crop irrigated using the drip irrigation method had the highest contents of carbohydrate, ash and fibre of 73.04%, 2.40% and 2.56% respectively. While plots scheduled using tensiometer and the ratio of irrigation amount to cumulative pan evaporation (IW/CPE) which resulted in 4 days irrigation interval gave the highest ash, fibre and carbohydrate contents 2.08%, 2.11% and 71.33% respectively compared to the fixed irrigation interval of 7 days The economic analysis result revealed that, the combination of drip irrigation and tensiometer schedule had the highest net farm income and benefit cost ratio of $695.2 and 3.20 respectively compared to $460.8 and 1.99 for sprinkler and $545.8 and 2.84 for furrow irrigation method. The findings of this study revealed that the combination of gravity drip irrigation method and soil moisture and climate based schedules that resulted in 4 days irrigation interval is the most economically viable alternative in maize

production for the semi-arid region environment of Nigeria for improved yield, higher water savings and water use efficiency as well as higher maize kernels quality. The study established infiltration models which are useful in the design of irrigation and drainage systems; soil and water characteristics models for scheduling irrigation and production model for describing the relationship between yield and actual evapotranspiration for making sound management decisions by farmers for optimum production. Further study is recommended on the viability of pressurized drip irrigation on field-scale in terms of yield improvement, water use efficiency, water savings and profitability of maize production.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

MENENTUKAN CARA IRIGASI YANG SESUAI DAN PENJADUALAN DALAM PENGELUARAN JAGUNG UNTUK PERSEKITARAN SEMI-ARID DI NIGERIA

Oleh

ALI UMAR BASHIR

Disember 2017

Pengerusi : MD. Rowshon Kamal, PhD
Fakulti : Kejuruteraan

Kekurangan air akibat kesan perubahan iklim dan permintaan global yang semakin meningkat untuk air dari pelbagai sektor termasuk pertanian telah menjadi kebimbangan global terutamanya di kawasan separa kemarau di mana pengairan merupakan satu-satunya alternatif untuk pengeluaran tanaman bagi memenuhi permintaan makanan penduduk yang semakin meningkat. Pengeluaran jagung di rantau separa kemarau di Nigeria bergantung pada sistem pengairan yang baik. Ini disebabkan oleh taburan hujan yang tidak menentu menyebabkan jumlah dan pengedaran dalam ruang dan waktu tidak sesuai untuk meningkatkan pengeluaran tanaman secara optimum. Petani di rantau ini menggunakan kaedah pengairan bawah tanah dan jadual selang pengairan tetap bagi pengeluaran tanaman jagung. Kaedah pengairan dan jadual yang digunakan oleh petani yang tidak cekap menyebabkan hasil pengeluaran yang rendah, penggunaan air yang tidak efisien, kualiti jagung yang rendah dan pendapatan bersih ladang yang tidak memuaskan. Oleh itu, terdapat jurang yang ketara di antara permintaan dan pengeluaran tanaman jagung bagi memenuhi keperluan makanan penduduk yang semakin meningkat. Tujuan kajian ini adalah untuk menentukan kaedah pengairan dan jadual pengairan yang betul dalam pengeluaran jagung di kawasan persekitaran semi-arid di Nigeria. Dua eksperimen lapangan dijalankan pada musim 2014 dan 2015 di Ladang Pengajaran dan Penyelidikan Politeknik Ramat Maiduguri, Borno Negeri yang terletak di rantau separa kemarau di Utara Nigeria. Eksperimen dijalankan melalui gabungan faktor kaedah pengairan dan kaedah penjadualan yang telah ditetapkan dalam bentuk batas yang lengkap yang menggunakan sembilan kaedah rawatan. Kaedah pengairan berada pada tiga tahap iaitu titisan, rembesan, dan kaedah pengairan bawah tanah. Kaedah penjadualan pengairan juga berada pada tiga tahap iaitu selang pengairan tetap (7hari), jadual kelembapan berasaskan tanah menggunakan *tensiometer* pada tahap pencetus 30 batang dan jadual berdasarkan iklim berdasarkan nisbah jumlah

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pengairan kepada penyejatan pan kumulatif 1 (1.0 IW / CPE). Rawatan secara rawak dijalankan pada plot dan direplikasi sebanyak tiga kali. Sebanyak 27 plot eksperimen telah digunakan untuk kajian ini. Sampel air diambil dari sumber air (telaga tiub) yang digunakan untuk pengairan tanaman jagung dan dianalisis untuk menentukan kesesuaiannya atau sebaliknya untuk pengairan. Sampel dianalisis untuk sifat fizikokimia menggunakan prosedur yang disyorkan dalam kaedah standard untuk pemeriksaan air dan air buangan dan nilai-nilai jumlah pepejal terlarut, nisbah natrium penjerapan, nisbah penjerapan magnesium, natrium karbonat dan nisbah kelly telah dikira. Parameter pertumbuhan, hasil dan hasil yang dicatatkan semasa pertumbuhan tanaman dan pembangunan tertakluk kepada Analisis Varians (ANOVA) untuk menentukan kesan kaedah pengairan dan jadual pengairan pada komponen pertumbuhan, hasil dan hasil jagung menggunakan Sistem Analisis Statistik (SAS 9.4) perisian. Ujian pelbagai ujian Duncan (DMRT) pada *p* 0.05 digunakan untuk membandingkan cara yang berbeza dan interaksi mereka. Analisis korelasi dilakukan untuk menentukan hubungan antara pertumbuhan dan parameter hasil dengan hasil. Penggunaan air tanaman dan penggunaan air pengairan menggunakan kecekapan, kualiti kernel jagung, prestasi sistem pengairan yang digunakan dari segi keseragaman pengagihan air, penjimatan air dan kecekapan pengairan telah dinilai. Daya maju ekonomi pengeluaran jagung di bawah kaedah pengairan dan penjadualan yang berbeza telah ditentukan. Hasil analisis kualiti air menunjukkan bahawa sumber air di kawasan kajian bebas daripada masalah kemasinan, kebolehtelapan dan ketoksikan didapati sesuai untuk kegunaan pengairan. Keputusan kajian menunjukkan bahawa pertumbuhan, hasil dan parameter hasil telah terjejas dengan ketara oleh kaedah pengairan dan jadual dalam kedua-dua musim yang semakin meningkat dengan prestasi yang lebih baik daripada titisan berbanding dengan kaedah pengairan dan saliran saliran. Hasilnya juga menunjukkan bahawa jagung yang ditanam lebih baik di bawah pemercik berbanding dengan kaedah pengairan salur. Hasilnya menunjukkan bahawa, plot yang dijadualkan menggunakan tensiometer dan nisbah jumlah pengairan kepada kaedah penyejatan pan kumulatif yang mengakibatkan selang pengairan 4 hari dilakukan dengan lebih baik berbanding selang tetap (7 hari). Nilai tertinggi penggunaan air tanaman dan penggunaan air pengairan menggunakan kecekapan 0.92 dan 0.73 kg/m^3 masing-masing diperoleh dari plot pengairan titisan yang dijadualkan dengan tensiometer berbanding dengan 0.73 dan 0.56 kg /m^3 untuk pemercik dan 0.66 dan 0.41 kg / m3 untuk saliran bawah tanah. Hasilnya menunjukkan bahawa penggunaan kaedah pengairan titisan telah menghasilkan penjimatan air sebanyak 17.31% dan 31.75% apabila dibandingkan dengan kaedah pengairan dan saliran. Keseragaman pengagihan air lebih tinggi dalam kaedah pengairan titisan dengan keseragaman pelepasan 91.2% berbanding pemercik dengan pekali keseragaman sebanyak 75% dan saliran bawah tanah dengan keseragaman pengagihan sebanyak 75%. Kecekapan pengairan kaedah pengairan, pemercik dan pengairan parit yang digunakan masing-masing adalah 80%, 76% dan 64%. Keputusan mengenai kesan kaedah pengairan dan jadual mengenai kualiti jagung menunjukkan tanaman jagung yang ditanam menggunakan kaedah pengairan titisan mempunyai kandungan tertinggi karbohidrat, abu dan serat masing-masing sebanyak 73.04%, 2.40% dan 2.56%. Walaupun plot yang dijadualkan menggunakan tensiometer dan nisbah jumlah pengairan kepada penyejatan periuk kumulatif (IW/CPE) yang menghasilkan 4 hari pengairan selang memberikan kandungan abu,

serat dan karbohidrat tertinggi masing-masing 2.08%, 2.11% dan 71.33% berbanding pengairan tetap selang 7 hari. Hasil analisis ekonomi mendedahkan bahawa gabungan pengairan titisan dan jadual tensiometer mempunyai nisbah pendapatan bersih dan nisbah kos manfaat sebanyak $ 695.2 dan 3.20 berbanding $ 460.8 dan 1.99 untuk penyiram dan $ 545.8 dan 2.84 untuk kaedah pengairan saliran bawah tanah. Penemuan kajian ini menunjukkan bahawa gabungan kaedah pengairan titisan graviti dan kelembapan tanah dan jadual berasaskan iklim yang menghasilkan selang 4 hari pengairan adalah alternatif yang paling ekonomik dalam pengeluaran jagung untuk persekitaran rantau separa gersang Nigeria untuk hasil yang lebih baik, lebih tinggi penjimatan air dan kecekapan penggunaan air serta kualiti empingan jagung yang lebih tinggi. Kajian ini menubuhkan model penyusupan yang berguna dalam reka bentuk sistem pengairan dan saliran model ciri tanah dan air untuk penjadualan pengairan dan model pengeluaran untuk menghuraikan hubungan antara hasil dan evapotranspirasi sebenar untuk membuat keputusan pengurusan yang baik oleh petani untuk pengeluaran yang optimum. Kajian lanjutan dicadangkan keatas kesesuaian pengairan titis bertekanan bagi penambahbaikan hasilan, kecekapan pengunaan, penjimatan air, penjimatan air dan keuntungan penghasilan jagung.

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I certify that a Thesis Examination Committee has met on 7 December 2017 to conduct the final examination of Ali Umar Bashir on his thesis entitled "Determining Proper Irrigation Method and Schedule in Maize Production for Semi-Arid Environment in Nigeria" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Desa bin Ahmad, PhD
Professor Ir.
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Azmi bin Dato Haji Yahya, PhD
Professor Ir.
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Khalina binti Abdan, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Budi Indra Setiawan, PhD
Professor
Bogor Agricultural University
Indonesia
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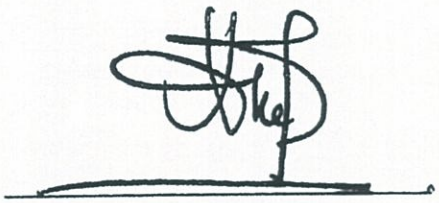

NOR AINI AB. SHUKOR, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 26 April 2018

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Md Rowshon Kamal, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Ahmad Fikri b. Abdullah, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Aimrun Wayayok, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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Signature: _____
Name of Member of Supervisory Committee: Dr. Ahmad Fikri b. Abdullah

Signature: _____
Name of Member of Supervisory Committee: Dr. Aimrun Wayayok

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TABLE OF CONTENTS

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LIST OF TABLES

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LIST OF FIGURES

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LIST OF ABBREVIATIONS

FAOSTAT	Food and Agricultural Organisation Statistical Year Book
FAO	Food and Agricultural Organisation
IITA	International Institute for Tropical Agriculture
NINCID	Nigeria National Committee on Irrigation and Drainage
MCM	Million Cubic Meters
PRB	Population Reference Bureau
UN	United Nation
TDS	Total Dissolved Solids
SAR	Sodium Adsorption Ratio
MAR	Magnesium Adsorption Ratio
RSC	Residual Sodium Carbonate
KR	Kelly Ratio
CWU	Crop water use
CPE	Cumulative Pan Evaporation
IW	Irrigation amount
CWUE	Crop water use efficiency
IWUE	Irrigation water use efficiency
CU	Coefficient of Uniformity
DU	Distribution Uniformity
EU	Emission Uniformity
FC	Field Capacity
PWP	Permanent Wilting Point
NWR	Net Water Requirement
NFI	Net Farm Income
BCR	Benefit Cost Ratio
CBS	Cost Benefit Ratio
SAS	Statistical Analysis Software

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

Maize *(Zea mays*) is a cereal crop that is ranked third in order of importance after wheat and rice in many countries including Nigeria (FAOSTAT, 2009). The origin of maize was South and Central America and it was introduced in the 16th Century by the Portuguese to Africa (Osagie and Eka, 1998). The total area used for growing maize all over the world was 184 million ha with a production of some 1016 million metric tonnes at an average yield of 5.52 t/ha in 2014 (FAOSTAT, 2014). Maize has appeared the most produced grain in the world exceeding rice and wheat in 1996 and 1997 respectively. Its production is growing at twice the yearly rate of rice and three times that of wheat (Fischer *et al*., 2014). In developing countries maize is produced on about 100 million hectares with almost 70% of its production coming from low and lower middle income countries (FAOSTAT, 2011). According to Rosegrant *et al*. (2008), maize demand will double by 2025 in the developing world and they predicted that by 2050, maize will become the crop with the highest production globally.

In Nigeria, the area under maize was about 6million ha in 2013 with a production of 7million tonnes giving an average yield of 1.4 to 1.5 t/ha (FAOSTAT, 2014). The production of the crop has been changed from that of a subsistence level to a major commercial grain crop with an annual growth rate of 4.2% compared with 2.3% and 1.9% for sorghum and millet respectively and 5% for rice between 1981 and 2012. Until recently, maize production has been limited to the rainy season. However, the introduction of irrigation facilities through the provision of dams and reservoirs and the development of *Fadama (*flood plains*)* has provided an opportunity for increased maize production in the semi-arid environment.

Maize is processed and consumed in a number of ways that vary with region and ethnic group. Alabi and Esobhawan (2006) reported a survey conducted in Nigeria which reveals that, maize accounts for about 43% of calorie intake. Apart from being a food crop, maize has equally become a commercial crop on which many industries depend on for raw materials (Abd El-Waheed and Ali, 2012). Some industrial uses of maize include insulating materials, plastic, pharmaceuticals, adhesives, chemicals, paints, dyes and soap among others. Maize contributes to about 80% of poultry feeds and this has great effect on the protein intake in Nigeria (IITA, 2008). Therefore, maize can be considered very vital to the economic growth of the nation through its contribution to food security and poverty alleviation. Nigeria, Africa's most populated nation with an estimated population of about 150 million is overwhelmingly dependent on agriculture, where more than 70% of its population

are involved (Adeniji, 2002). The climate of most part of Nigeria is predominantly arid or semi-arid.

The prosperity of agriculture provides the impetus to establishing or strengthening the industrial base of the country and thereby raising the overall prosperity of the nation. Majority of farmers in Nigeria as in among other developing countries, are at subsistence level and hence cannot meet their food and fibre requirements. FA0 (2015) reported that, food insecurity and poverty are still on the increase in many sub-Saharan countries, including Nigeria. The report revealed that the region recorded the highest prevalence of hunger compared to any other region with about 220 million hungry people between 2014 to 2015. The gap between the domestic food supply and demand in Nigeria is unfortunately an increasing one. The Human Development Report by United Nations (Malik, 2014) shows that about 84.5% of the population lives below $2 per day. This economic condition is worse in the rural areas where over 70% of the people reside and earn their leaving through farming. Efforts should therefore be geared to increase food production to meet the demand for the increasing population. Irrigation that had the highest contribution to increasing the global food production is the only alternative solution to this problem (Adeniji, 2002).

Irrigation is an agricultural practice designed to supplement the water available from precipitation and the contribution to soil moisture from ground water by providing the required quantity of water and at the time needed to replenish soil moisture to the required level for optimum crop production (Zwart and Bastianssen, 2004; Hoffman *et al.*, 2007 and Nagy, 2008). Irrigation is therefore a risk management tool for agricultural production. The impact of irrigation is greatest in arid and semi-arid regions as well as in humid and sub-humid climates during drought periods. Yields from irrigated land are higher and more consistent than the yields from rain fed areas. Irrigation therefore plays a significant part in sustaining food production for the ever increasing population. Irrigation guarantees crop production and provides economic stability to farmers and communities. Drastig *et al*. (2016) described irrigation as one of the most effective means which guarantees income to farmers. Irrigation has enabled the productive use of waste effluent from various food processing and municipal sewage plants. Other uses of irrigation include the conjunctive application of chemicals such as fertilizers, pesticides, herbicides and defoliants with the irrigation water. Irrigation can also be used for cooling crops, dissolving hard pans and leaching undesirable salts from the root zone of plants. Irrigation has also greatly helped in stabilizing food production and prices over the years (Rosegrant *et al.,* 2002). Today irrigated agriculture continues to make civilization less dependent on the vagaries of climate for food and fibre requirement to sustain life. The technique of replenishing the soil water deficit by applying irrigation water is referred to as an irrigation method (Drastig *et al*., 2016). Irrigation methods are broadly classified into surface, sprinkler, trickle and subsurface irrigation on the basis of the modes of water application and their associated overall efficiencies (Adeniji, 1992; Ali, 2011). Irrigation methods have specific applications that are based on several factors, among which the most relevant are the crop, soil

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type, topography and water availability and quality. The application efficiencies of the methods vary and depend on its design, management and operation (Holzapfel *et al*., 2009).

1.2 Statement of Problem

In the face of the dwindling availability of water resources in the 21st century (Turral *et al*., 2011), it's prudent use becomes inevitable. Irrigation accounts for more than 70% of water resources consumption globally and locally (UN, 2009 and FAO, 2011). Irrigation has long been recognized as a very important instrument in achieving food security. But ensuring this food security and controlling environmental degradation are still some of the major social challenges in many countries, including Nigeria (Bashir and Duru, 2002; Mofoke, 2002). Irrigation methods are thus under pressure to double-up their productivity with lower supplies of water (FAO, 2011; Postel, 2001; Levido *et al*., 2014).

The predominant source of water in the semi-arid region of Nigeria for maize production is from tube wells, due to the fact that most of the rivers/ponds in the region get dried up untimely thus inflicting moisture stress on crops resulting in low yield and economic loss. But the suitability or otherwise of water from tube wells for irrigation in the region has not been ascertained despite the fact that water of suitable quality is necessary for crop production due to its effect on growth, yield and quality of crops. Irrigation using water of questionable quality results in salinity, toxicity and permeability problems which affect the ability of plants to absorb water from the soil resulting in reduced growth and wilting. Kang *et al*. (2010) reported a decrease in growth and yield of maize by 2% for every 1 ds/m increase in salinity of irrigation water. In another research, Blanco *et al*. (2008) reported plant height of 154cm using water with EC value of 0.3 ds/m compared to a plant height of 100cm obtained from plots irrigated with water with EC value of 4.5 ds/m. Similarly, Amin *et al*. (2015) found an increase in maize yield by 14.85% using water with an electrical conductivity of 0.4ds/m relative to 4ds/m.

Maize is commonly irrigated using furrow irrigation method in the semi-arid region of Nigeria (Ahmed *et al*., 2000). But due to its low application efficiency of 54% (Aljamal *et al*., 2001), only 1.8 t/ha of maize is obtained compared to the world average of 5.3 and to 7.8 and 9.1 t/ha Egypt and Mauritius, respectively (FAOSTAT, 2014). Bashir and Akande (2017) reported a wide gap in maize yield from the use of furrow irrigation compared to drip irrigation method, with 2630 kg/ha from furrow irrigation compared to the yield of 5684 kg/ha obtained from the drip irrigation method in the semi-arid region of Nigeria. Similarly, Usoh *et al*. (2017) reported a 36% drop in furrow irrigated maize yield relative to those obtained using drip irrigation method in Nigeria. In a similar research, Kharru *et al*. (2011) reported that furrow irrigated wheat yield was 28% less relative to drip irrigated wheat in the semi-arid region of Morocco. Erdem *et al*. (2006) also found a 40% drop in furrow irrigated tuber yield relative to those obtained under drip irrigation. In terms of water

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use efficiency, furrow irrigation method has lower irrigation water use efficiency compared to drip irrigation method as confirmed by the work of Ghamarnia *et al.* (2013) that reported significant increase in maize irrigation water use efficiency of 1.29 kg/m^3 and water savings of 36% from drip irrigation method compared to irrigation water use efficiency of 0.99 kg/m^3 from furrow irrigation method. Similarly, Cetin and Bilget (2002) reported higher water use efficiency of 4.87kg/m^3 in drip irrigation compared to 3.87kg/m^3 in furrow irrigation method. Yavuz *et al.* (2012) reported 24 % drop in irrigation water use efficiency under furrow irrigation relative to drip irrigation method. The quality of maize kernels produced using furrow irrigation is low due to its lower water application efficiency of 60% (Ammoson *et al.*, 2016). Ghamarnia *et al.* (2013) obtained lower carbohydrate content of 68.24% from maize irrigated using furrow irrigation method relative to drip irrigation which produced carbohydrate content of 69.29%. Furrow irrigation is not economically viable compared to drip irrigation method. Baranchuluun *et al.* (2016) reported a lower benefit cost ratio of 2.12 from furrow irrigation method compared to the benefit cost ratio 3.6 obtained using drip irrigation method. Sprinkler and drip irrigation methods remain more efficient relative to any of the surface irrigation methods (Ayars *et al.*,1999; Dogan and Kirnak,2010). But these pressurized irrigation methods are rarely practised by Nigerian farmers probably due to lack of their technical know-how, unawareness on their benefits or due to high initial expenditure required for installation. Thus, there is still a growing gap between the demand of maize and its production. It is obvious from above that developing an operational irrigation method and schedule for efficient use of the limited water resources and for the growth and production of maize is crucial in the northern semi-arid region of Nigeria. Furthermore, despite the preference of pressurize irrigation methods over the surface irrigation methods; their productivity and profitability or otherwise for Maize have not been evaluated in dry semi-arid region of Nigeria.

1.3 Study Justification

Agriculture currently utilizes about 70% of the water withdrawal in the world primarily for irrigation purpose (Chartzoulakis and Bertaki, 2015). According to Fereres and Connor (2004) irrigated systems represents about 40% of the global food production and uses only about 18% of the land area allocated to food production There will be increasing pressure on freshwater resources due to rising demand for food, livestock feed, and biofuels as well as global climate change (Falkenmark *et al.*, 1998; Rosegrant *et al.*, 2009). There will be increasing competition for scarce water in major irrigated cropping systems of the world (Postel, 1998; Perry, *et al.*, 2009; Rosegrant *et al.*, 2009). The dwindling water availability has made it necessary to improve the way water is used in agriculture.

In the arid and semi-arid areas of Nigeria, water is the major constraint in crop production. Rainfall is extremely irregular, to the extent that the amount and distribution in space and time had not been ideal to optimally support crop production adequately (Dibal et al., 2006). The high temperature, high soil

evaporation rate, poor water holding capacity of soils and the vagaries of climate change are among others responsible for reducing water availability to crops. But an adequate amount of water in the soil is necessary for optimum growth and yield of crops (Igbadun et al., 2007).

Maize production using drip irrigation method was experimented in many parts of the world and the results were found to be successful (Karlen and Camp, 1985; Adamsen, 1992; Abu-Awwad, 1994; Darusman et al., 1997a; Yazar et al., 2002; Colombo and Or, 2006; El-Hendawy, et al., 2008; Howell et al., 1997; Karimi and Gomrokchi, 2011; Oktem et al., 2003; Wentao et al., 2006).

In Nigeria, hunger and poverty are still prevalent amongst the population especially in the arid and semi-arid regions due to low productivity of their farming practices. Maize cultivation in the semi-arid region of Nigeria relies widely on irrigation and is mainly irrigated using conventional furrow irrigation method without soil moisture or climate based scheduling. There is the need therefore, to determine the proper and the most economically viable irrigation method and schedule such that the plant receives the required amount of water at the right time for optimum maize production to meet the increasing demand for food, livestock feeds and biofuel for the growing population. The result of this research would greatly help farmers and scientist in making decision regarding the best management practices in the planning of irrigated maize farming.

1.4 Objectives of study

The main objective of the study is to determine the appropriate irrigation method and schedule for optimum maize production specifically in the semi-arid region of Nigeria.

The specific objectives were to:

1. Analyse the suitability of ground water which is predominantly used for irrigation in the area.
2. Determine the effects of irrigation methods and schedules on the growth, yield and yield parameters, maize quality and water use efficiency of maize.
3. Analyse the economic viability of maize production under furrow, sprinkler and drip irrigation methods in the region.

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1.5 Scope and Limitations

The study focused on the determination of proper irrigation method and schedule for maize production in the semi-arid region of Nigeria. Two field experiments were conducted in the 2014 and 2015 seasons at the Teaching and Research Farm of Ramat Polytechnic Maiduguri, Borno State which is located in the semi-arid region of Northern Nigeria to establish an economically viable combination of irrigation method and schedule for improved maize yield and higher use efficiency in the region. The study was limited to the evaluation of three (3) irrigation methods namely; furrow, sprinkler and drip irrigation methods. Similarly, irrigation schedules were also limited to three (3) levels namely; fixed irrigation interval, soil moisture based schedule (tensiometer) and climate based schedule (ratio of irrigation amount to cumulative pan evaporation).

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