UNIVERSITI PUTRA MALAYSIA

EFFECTS OF SOIL MOISTURE CONTENT AND FERTILIZER SOURCE ON GROWTH AND YIELD OF SWEET CORN

MOHAMED ABDIRAHMAN SHEIKH MUHUMED

FP 2013 74

EFFECTS OF SOIL MOISTURE CONTENT AND FERTILIZER SOURCE ON GROWTH AND YIELD OF SWEET CORN

By

MOHAMED ABDIRAHMAN SHEIKH MUHUMED

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

September 2013

COPYRIGHT

DEDICATION

TO MY BELOVED PARENTS AND FAMILY

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

EFFECTS OF SOIL MOISTURE CONTENT AND FERTILIZER SOURCE ON GROWTH AND YIELD OF SWEET CORN

By

MOHAMED ABDIRAHMAN SHEIKH MUHUMED

September 2013

Chairman: Prof. Shamshuddin Jusop, PhD

Faculty: Agriculture

Corn (*Zea mays L.*) is one of the most important cereal crops worldwide, next to wheat and rice. In Malaysia, corn can grow successfully as the climate of the country is suitable for the crop. However, it is a minor crop even though the demand for corn increases over the years. Corn is imported yearly to satisfy the country's needs. The main challenges for corn production are low soil fertility, low pH and water shortage. Thus, to overcome these problems, two studies were conducted in a rain shelter at Field 2, Faculty of Agriculture, Universiti Putra Malaysia, Serdang, Malaysia.

The objectives of first experiment were to determine the effect of soil moiture content and fertilizer sources on the growth and yield of sweet corn and to evaluate the effect of their interaction on the yield of the sweet corn. The treatments were four soil moiture contents (Smc) namely: 100% (Smc1), 90% (Smc2), 80% (Smc3), and 70% (Smc4), and four

fertilizer sources namely: mineral fertilizer (NPK), goat manure (GM), poultry manure (PM) and without fertilizer (control). The treatments were arranged in split-plot design as the moisture content was assigned as main plot factor while fertilizer sources as sub plot factor. The results showed that the total dry matter (all above ground excluding yield) significantly ($P<0.05$) increased with the increase in soil moisture content. 100% soil moisture content (Smc1)) with goat manure (GM) gave higher biomass compared to PM and control treatment. Highest root dry weight was achieved from 90% soil moisture content (Smc2) with poulry manure (PM). In terms of yield components, interaction between soil moisture content and fertilizer sources significantly ($P<0.05$) affected the plant cob and ear weight. Both organic (GM and PM) and inorganic (NPK) fertilizers enhanced cob and ear weight at Smc1 and Smc2 while NPK and GM gave higher grain weight at Smc1and Smc2 compared to PM and control treaments. Positive correlation between total dry matter, yield components and nutrient uptake was observed, indicating better crop response to soil moisture and fertilizer (organic and inorganic) application.

The second experiment was conducted in Field 2 under rain shelter to evaluate the effect of soil moisture contents and inorganic fertilizer levels on the growth and yield performance of sweet corn and to determine the maximum NPK rate that would enhance high growth and yield of sweet corn. Three soil moisture contents and four fertilizer levels were used namely: 90% (Smc2), 80% (Smc3) and 70% (Smc4), while NPK fertilizer levels were: F1 (0:0:0 kg ha^{-1}), F2 (60:30:45 kg ha^{-1}), F3 (120:60:90 kg ha^{-1}) and F4 (180:90:135 kg ha^{-1}). The results showed that total dry matter yield significantly ($P<0.05$) increased with increase in soil moisture content. 90% (Smc2) treatments with 150% (F4) gave higher shoot dry weight compared to the other fertilizer levels. Soil moisture

contents and fertilizer levels significantly ($P<0.05$) influenced the yield components. Ear, cob and grain weight were found to be higher in 100% smc1 with fertilizer level 150% (F4) of recommended rate. When fertilizer level was increased from 100% (F3) to 150% (F4) of recommended rate then ear (25%), cob (39%), and grain (23%) also increased. This study showed that N, P, K, Ca and Mg uptake by the root and shoots was enhanced as the fertilizer level increased. This indicates that corn responded to fertilizer application by increasing total dry weight as supported by positive correlation between total dry matter (root and shoot) and N, P, K, Ca and Mg uptake by the roots and shoots.

In conclusion, the current study revealed that sweet corn water demand is absolutely high in which total dry matter and yield components increased with increase in soil moisture contents for both experiments. In terms of fertilizers, organic fertilizers enhanced crop biomass and yield components to a level which can be considered as an alternate to chemical fertilizer application. Finally, in terms of NPK fertilizer levels, the current recommended fertilizer rate is not enough and 150% (F4) seems to be the best choice as this study has shown.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KESAN KANDUNGAN KELEMBAPAN DAN SUMBER PEMBAJAAN KE ATAS TUMBESARAN DAN HASIL JAGUNG MANIS

Oleh

MOHAMED ABDIRAHMAN SHEIKH MUHUMED

September 2013

Penyelia : Shamshuddin Jusop, PhD

Fakulti : Pertanian

Jagung (*Zea mays. L.)* adalah salah satu daripada tanaman bijirin yang sangat penting di dunia selain daripada gandum dan padi. Di Malaysia, jagung boleh membesar dengan baik dan suhu adalah bersesuaian dengan keperluan tanaman tersebut. Wala bagaimanapun, jagung merupakan tanaman minor berbanding tanaman lain seperti padi, sedangkan permintaan tanaman adalah meningkat baru-baru ini dan sejumah besar jagung diimport setiap tahun untuk memenuhi keperluan negara. Cabaran utama dalam pengeluaran jagung adalah kesuburan tanah dan pH yang rendah serta masalah air. Untuk mengatasi masalah-masalah ini, dua kajian telah dijalankan di kawasan teduhan hujan bertempat di Ladang 2, Fakulti Pertanian, Universiti Putra Malaysia, Serdang, Selangor, Malaysia.

Objektif pertama kajian adalah untuk menentukan kesan kandungan kelembapan tanah titis dan sumber baja pada tumbesaran dan hasil jagung manis. Terdapat 4 keadaan

kelembapan tanah iaitu 100% kelembapan tanah (Smc1), 90% kelembapan tanah (Smc2), 80% kelembapan tanah (Smc3) dan 70% kelembapan tanah (Smc3) dan terdapat 4 sumber baja iaitu baja mineral (NPK), tahi kambing (GM), tahi ayam (PM) dan juga kawalan (tanpa baja). Rawatan-rawatan tersebut disusun dalam reka bentuk plot berpecah-pecahan di mana pengairan adalah faktor utama manakala sumber baja sebagai faktor sub-plot. Keputusan menunjukkan jumlah bahan kering (semua di atas tanah tidak termasuk hasil) adalah nyata ($P < 0.05$) bertambah dengan peningkatan kekerapan pengairan. kelembapan tanah harian dengan baja tahi kambing menunjukkan biomas yang paling tinggi berbanding dengan rawatan baja tahi ayam dan kawalan. Terdapat persamaan di mana berat kering akar adalah paling tinggi dari pembajaan 90% kelembapan tanah berbanding tahi ayam. Untuk komponen hasil, interaksi antara kandungan kelembapan dan pembajaan adalah nyata ($P<0.05$) dan ia memberi kesan kepada berat batang dan tongkol buah. Kedua-dua baja organik (tahi kambing dan tahi ayam) dan baja tak organik (NPK) menambahkan berat batang dan tongkol buah pada Smc1 dan Smc2 manakala NPK dan tahi kambing menghasilkan berat yang agak baik pada Smc1 dan Smc2 berbanding tahi ayam dan kawalan. Terdapat korelasi positif antara jumlah bahan kering, komponen hasil dan pengambilan nutrien telah diperhatikan yang mana menunjukkan tindakbalas tanaman adalah lebih baik kepada aplikasi pembajaan.

Kajian kedua telah dijalankan di Ladang 2 di kawasan teduhan hujan untuk menilai kesan kekerapan pengairan titis dan peringkat pembajaan terhadap tumbesaran dan hasil jagung manis. 3 kandungan kelembapan tanah dan 4 peringkat pembajaan iaitu Smc2: 90% kandungan kelembapan tanah, Smc3: 80% kandungan kelembapan tanah dan Smc4: 70% kandungan kelembapan tanah, manakala peringkat pembajaan NPK adalah; F1 (0:0:0 kg

ha^{-1}), F2 (60:30:45 kg ha^{-1}), F3 (120:60:90 kg ha^{-1}) dan F4 (180:90:135 kg ha^{-1}). Keputusan menunjukkan bahawa jumlah hasil kering adalah nyata ($P<0.05$) bertambah dengan pertambahan kandungan kelembapan tanah. Rawatan 90% kandungan kelembapan tanah, (Smc2) dengan 150% (F4) telah menunjukkan berat kering pucuk yang paling tinggi berbanding dengan peringkat pembajaan yang lain. Selain itu, kandungan kelembapan tanah, dan peringkat pembajaan adalah nyata ($P<0.01$) dan mempengaruhi komponen hasil. Berat batang, tongkol dan butir buah ditemui paling tinggi dalam 90% kandungan kelembapan tanah, (Smc2) dengan peringkat pembajaan 150% (F4) yang telah disyorkan. Apabila peringkat pembajaan ditingkatkan dari 100% (F3) kepada 150% (F4), tongkol (25%), batang jagung (39%), butir jagung (23%) juga adalah meningkat.

Kajian ini menunjukkan pengambilan N, P, K, Ca dan Mg oleh akar dan pucuk telah bertambah dengan peningkatan peringkat pembajaan. Ini menunjukkan jagung telah memberi tindakbalas kepada penggunaan baja dengan meningkatkan jumlah berat kering seperti disokong korelasi positif antara jumlah bahan kering (akar dan pucuk) dan pengambilan N, P, K, Ca dan Mg oleh akar dan pucuk. Kesimpulannya, kajian semasa menunjukkan bahawa kandungan kelembapan tanah, bagi jagung manis adalah tinggi yang mana jumlah bahan kering dan komponen hasil bertambah dengan peningkatan kekerapan pengairan untuk kedua-dua kajian. Selain itu, baja organik meningkatkan biomas tanaman dan komponen hasil ke peringkat yang boleh dipertimbangkan sebagai alternatif lain selain penggunaan baja kimia. Untuk terma peringkat baja NPK, kadar pembajaan semasa yang telah disyorkan adalah tidak mencukupi dan 150% (F4) adalah merupakan pilihan terbaik seperti yang ditunjukkan dalam kajian ini.

ACKNOWLEDGEMENTS

All praises are for Allah, the most gracious, the most merciful who taught human with means of pen and writing and who taught what men previously do not know.

I would like to express my heartfelt appreciation to Professor Shamshuddin Jusop, Chairman of my supervisory committee for his constant advices and guidance, tolerance and encouragements, fruitful criticism, close supervision and patience in reading this dissertation and my manuscript thoroughly in short time. He offered to me a higher opportunity for the improvement of my scientific knowledge and research work. Moreover, he made available all the research materials timely to enable me complete the research work smoothly and on time.

I would like to gratefully acknowledge to Dr. Christopher Teh Boon Sung, member of my supervisory committee for his valuable advices, guidance and scholarly criticism throughout my study time. I thank him for sparing his precious time whenever I need.

I am also thankful, to Dr. Puteri Edaroyati Wahab, member of my supervisory committee for her advices and guidance particularly in my writing during the preparation of final results presentation. I would like to especial thanks to all my lecturers, staff of Field 2 and in the Department of Land Management for their kindness and moral support by all means during my study.

My sincere appreciations and thanks are extended to Horn of Africa Aid (HAA) that awarded me scholarship to pursue Master degree in Malaysia and their endless assistance and help throughout my study time. Special thanks are extended to Mr. Mohamed Omer

(head of the scholarship division of HAA) and Mr. Khalid Ahmed Mohamed (Financial Secretary of HAA) for their constant cooperation. Without their cooperation and help, the completion of my study would not have been possible. I am also thankful, to all those who directly and indirectly assisted me.

I would like to express my heartfelt thanks to my beloved parents and siblings who one way or the other made my dreams to achieve this degree, and their constant prayers and encouragements to accomplish my goals. Allah may continue to reward you abundantly.

I express my profound appreciations to my wife Sahra Omer, for her forbearance, constant prayer and encouragements and sharing my parts of responsibilities at her shoulders for the management of the family matter during my long absence from home. The same thanks are extended to my youngest sister, Madina, who really looked after my newly born daughter. Special thanks are extended to my daughter Muna Mohamed, who tolerated and sacrificed with patience my fatherly love for her.

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

Shamshuddin Jusop, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Christopher Teh Boon Sung, PhD
Senior Lecturer
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Puteri Edaroyati Megat Wahab, PhD
Senior Lecturer
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

_____

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AA	Auto Analyzer
AAS	Atomic absorption spectrophotometer
Al	Aluminum
ANOVA	Analysis of Variance
B	Block
BD	Bulk density
Ca	Calcium
CEC	Cation exchangeable capacity
CRD	Completely Randomized Design
CV	Coefficient of variance
DAS	Days after sowing
Df	Degree of freedom
DMNRT	Duncan's Multiple New Range Test
EC	Electrical conductivity
ET	Evapotranspiration
F	Fertilizer level
FAO	Food and Agriculture Organization of the United Nations
FYM	Farm yard manure
GM	Goat manure
GML	Ground magnesium limestone
ICP	Inductively coupled plasma
K	Potassium

MARDI	Malaysian Agricultural Research and Development Institute
Mg	Magnesium
MOP	Muriate of potash
N	Nitrogen
NS	Not significant
OM	Organic matter
P	Phosphorus
PM	Poultry manure
PWP	Permanent wilting point
r	Correlation Coefficient
RFR	Recommended fertilizer rate
SAS	Statistical Analysis System
SPAD	Soil and Plant Analyzer Development
SMC	Soil moisture content
TSP	Triple super phosphate
UPM	Universiti Putra Malaysia
USDA	United States Department of Agriculture
WP	Wilting point

CHAPTER 1

INTRODUCTION

As the world population increases, the demand for food for the growing population increases. By the year 2025, it is expected that human population in the world will increase to over 8-9 billion which means that the consumption of the food will be higher than present (Lascano *et al*., 2007). To overcome reduction of the food, it is necessary to produce double and improve agricultural production. It is not only important to increase the food production but also to sustain the production capacity in agricultural sector (Rawlins and Raats, 1975). However, there are many constraints towards the improvement of the agricultural production. Two of the major problems are water scarcity and low soil fertility.

Water scarcity is the main problem affecting agricultural production in developing countries particularly in arid and semi-arid regions. Water scarcity is due to long term drought, high demand for water in households as well as irrigation and mismanagement of available water resources; these problems have threatened the sustainability of agricultural development. There is evidence that more than 40% of the people in our planet are affected by water scarcity and by the year 2025, 1.8 billion people will be living in countries with absolute water scarcity (Lascano *et al*., 2007). Two-third of the world's population suffered from water stress conditions (Forouzani *et al*., 2012). Therefore, irrigation is very important for the countries with water scarcity to improve crop production for their life sustainability.

The available water resources will decrease with increasing the number of population. This challenge is common among the all developing countries especially in arid and semi-arid regions of the world (Hassanli *et al*., 2009). This is due to the fact that most arid countries are dry and receive less than one third of the world's annual precipitation. One approach to overcome this problem and improve the crop productivity is by improving the irrigation technology and managing irrigation scheduling.

Fresh water and underground water use are other alternative ways for water resource management particularly in countries with water scarcity (Kirda, 2002). In this study, soil moisture content is considered as one of the most important factor in affecting soil water conditions, fertilizer use efficiency, crop yield quantity and plant biomass weight (El-Hendawy et *al*., 2008a). Corn is an important crop in the world due to its diversified use. In Malaysia, corn is partly grown on highly weathered acidic soils. The yield is low due to low pH and high Al concentration (Shamshuddin and Fauziah, 2010). Climatic conditions in Malaysia are suitable for corn cultivation and sustainability. However, the country imports large quantity of corn per year to cover the country's demand for corn. This phenomenon is not strange as corn is not a Malaysian staple food. Corn is grown in other parts of the world particularly semi-arid countries like Somalia and developed countries like United States of America and Canada. However, current available literature illustrates that corn is susceptible to water stress conditions.

Maize, corn and Indian corn are the names which always appear in the literature. Avoiding the confusion among them, maize is the common name of corn; *a Zea mays is* the scientific name for corn. *Zea mays* is a Greco-Latin name meaning a wheat-like grain

and Mays is derived from the Taino word *Mahiz*, which means life-giver. *A Zea may is* in the Gramineae (*Poaceae*) family. For further illustration, *Zea mays* is one of three grasses in the Maydeasubtribe (corn, *teosinte* and *Tripsacum*). United State is one of the few countries that use the word corn (Shultz, 2008). According to the cereal production statistics, corn ranks second to wheat. It is the most important staple food in sub-Saharan Africa, alongside rice and wheat; the three are the most important cereal crops in the world. However, its production is negatively affected on exhausted soil and generally observed that it fails to produce good grain yield unless adequate fertilizers are applied (Jaliya *et al*., 2008)

In total, there are 80 million ha planted with corn, mainly in developing countries; this represents 60% of the world's maize area, though only 40% of global production is harvested from the third world. China, Mexico, Brazil and Argentina are the four countries accounted 67% of the total third world maize production (Sheaffer, 2009). However, globally the United States leads the world in corn production with a high percentage of 39% in 2006-2007; China and Brazil are the two countries after the United States in corn production with 21% and 6%, respectively. The United States is also the top exporter of corn, followed by Japan (Shultz, 2008).

Sweet corn is used as an appetizer or can be used as grains and "ugaly" (local food), especially in East Africa countries like Somalia. Compared with other varieties of corn, fresh consumption of sweet corn is more preferable due to its soft grains, thin shells, high concentration of sugar and tastefulness (Farsiani *et al*., 2011). Sweet corn has sweeter taste than any other types of corn especially before the ripening and drying

because the endosperm consists of sugar as well as starch. There is still not enough research to determine the optimum soil moisture content for corn crop; therefore, the evaluation of different soil moisture contents and application of different fertilizer sources is necessary. Apart from the water scarcity, there are other major problems which cause decline and reduction of agricultural produce. These include low soil fertility and poor water holding capacity. Low fertility exists in tropical countries like Malaysia due to heavy rain fall throughout the year which causes leaching of nutrients. Therefore, to overcome these problems there is a need for external inputs to improve soil fertility. This study seeks to evaluate organic and inorganic fertilizer application effects on the soils as well as to manage irrigation water.

The following were the objectives of the study:

i. To determine the effects of different soil moisture contents on the growth and yield of sweet corn;
ii. To assess the effect of organic and inorganic fertilizers on the growth and yield of sweet corn;
iii. To determine the interaction effect between fertilizers and soil moisture content on the growth and yield of corn under sandy clay soil condition; and
iv. To determine the maximum rate of NPK that would produce high growth and yield.

REFERENCES

Abbasi, M. K., Hina, M., Khalique, A., & Khan, S. R. (2007). Mineralization of three organic manures used as nitrogen source in a soil incubated under laboratory conditions.*Communications in soil science and plant analysis, 38*(13-14), 1691-1711.

Adediran, J.A. (2004). Application of organic and inorganic fertilizers for sustainable maize and cowpea yields in Nigeria. *Journal of plant nutrition*, 27(7), 1163-1181.

Adeniyan, O., & Ojeniyi, S. (2006). Effect of poultry manure, NPK 15-15-15 and combination of their reduced levels on maize growth and soil chemical properties. *Nigerian Journal of Soil Science, 15*(1), 34-41.

Ali, J., Jehan, B., Shafi, M., Sherin, Kh., & Wajid, A. Sh. (2002). Effects of various levels of N and P on yield and yield components of maize. *Journal of Agronomy* 1(1):12-14.

Amer, K. H. (2010). Corn crop response under managing different irrigation and salinity levels. *Agricultural Water Management, 97*(10), 1553-1563.

Anac, S., Ul, M.A., & Tuzel, I.H. (1992). Corn yield as affected by deficit irrigation. In: Fyen, J., Mwendera, E., Badji, M. (Eds.), Advances in Planning Design and Management of Irrigation Systems as Related to Sustainable Land Use. *Center for Irrigation Engineering (CIE), European Committee for Water Resources Management (ECOWARM), Belgium*.

Arthur, E., Cornelis, W. M., Vermang, J., & De Rocker, E. (2011). Amending a loamy sand with three compost types: impact on soil quality. *Soil Use and Managemen, 27*, 116–123.

Ashiq, S., Javed, H.I., Ali, Z. & Ullah , I. (2003). Response of maize cultivars to different N-P levels under irrigated condition in Peshawar valley. *Pakistan Journal of Biological Science* 6(14):1229-1231.

Assouline, S. (2002).The effects of micro drip and conventional drip irrigation on water distribution and uptake. *Soil Science Society of America Journal*, 66(5), 1630-1636.

Aydinsakir, K., Erdal, S., Buyuktas, D., Bastug, R., & Toker, R. (2013). The influence of regular deficit irrigation applications on water use, yield, and quality components of two corn (< i> Zea mays</i> L.) genotypes. *Agricultural Water Management*, *128*, 65-71.

Bakht, J., Ahmad, S., Tariq, M., Akber, H., & Shafi, M. (2006). Response of maize to planting methods and fertilizer N. *Journal of Agricultural and Biological Science, 1*(3), 8-14.

Barnhisel, R., & Bertsch, P.M (1982). Aluminum. P. 275-300. In A.L. Page et al. (ed) Method of soil analysis. Part 2.2nd ed. Agron. *Monogr.9. ASA and SSSA, Madson, WI.*

Bhattacharyya, R., Kundu, S., Prakash, V., & Gupta, H.S. (2008). Sustainability under combined application of mineral and organic fertilizers in a rain fed soybean-wheat system of the Indian Himalayas. *European Journal of Agronomy* 28: 33-46.

Blaise, D., Singh, J., Bonde, A., Tekale, K., & Mayee, C. (2005). Effects of farmyard manure and fertilizers on yield, fibre quality and nutrient balance of rainfed cotton (< i>Gossypium hirsutum</i>). *Bioresource technology*, *96*(3), 345-349.

Boateng, S. A., Zickermann, J., & Kornahrens, M. (2009). Poultry manure effect on growth and yield of maize. *West African Journal of Applied Ecology*, *9*(1).

Bray, R.H., & Kurtz, L.T. (1945). Determination of organic and available forms of phosphorus in soils. *Soil Science*, 59: 39-45.

Bremner, J.M. (1960). Determination of soil nitrogen by Kjeldahl method. *Journal of Agricultural Science* 55:11-31.

Bruns, H.A. & Abel, C. A. (2003). Nitrogen fertility effects on Bt ∂-endotoxin and nitrogen concentration on maize during early growth. *Agronomy Journal*, 95:207-211.

Çakir, R. (2004). Effect of water stress at different development stages on vegetative and reproductive growth of corn. *Field Crops Research*, *89*(1), 1-16.

Cerrato, M.E., & Blackmer, A.M. (1990). Comparison of models for describing corn yield response to nitrogen fertilizer. *Agronomy Journal 82: 138-143*

Chapman, H.D. (1965). Determination of cation exchange capacity. In C.A.Black (Ed), Methods of soil analysis, 2(1), 891-900. Agronomy Mongor. 9. ASA, Madison, WI.

Coelho, E. F., & Or, D. (1999). Root distribution and water uptake patterns of maize under surface and subsurface drip irrigation. *Plant Soil* 206, 123–136.

Campos, H., Cooper, M., Habben, J.E., Edmeades, G.O., & Schussler, J.R. (2004). Improving drought tolerance in maize: a view from industry. *Field Crops Research.* 90,19–34.

Cavero, J., Farre, I., Debaeke, P., & Faci, T.M. (2000). Simulation of maize yield under water stress with EPIC phase and Cropwat models. Agronomy Journal. 92, 679–690.

Colomb, B., Kiniry, J. R., & Debaeke, P. (2000). Effect of soil phosphorus on leaf development and senescence dynamics of field-grown maize. Agronomy Journal, *92*(3), 428-435.

Cooperband, L., Bollero, G., & Coale, F. (2002). Effect of poultry litter and composts on soilnitrogen and phosphorus availability and corn production. *Nutrient Cycling in Agroecosystems, 62*(2), 185-194.

Das, P.C. (1993). Manure and fertilizers. Kalyani Publisher, New Delhi P130.

Delin, S. (2004). Within-variations in grain protein content: Relationships to yield and soil nitrogen consistency in maps between years. *Precise Agriculture*, 5:565-577.

Di Paolo, E., & Rinaldi, M. (2008). Yield response of corn to irrigation and nitrogen fertilization in a Mediterranean environment. *Field Crops Research, 105*(3), 202-210.

Edmeades, G. O., Bolaños, J., Hernandez, M., & Bello, S. (1993). Causes for silk delay in a lowland tropical maize population. *Crop Science, 33*(5), 1029-1035.

Efthimiadou, A., Bilalis, D., Karkanis, A., & Froud-Williams, B. (2010). Combined organic/inorganic fertilization enhance soil quality and increased yield, photosynthesis and sustainability of sweet maize crop. *Australian Journal of Crop Science, 4*(9), 722-729.

Efthimiadou, A., Bilalis, D., Karkanis, A., Froud-Williams, B., & liftherochorinos, I. (2009). Effects of Cultural System (Organic and Conventional) on Growth, Photosynthesis and Yield Components of Sweet Corn (*Zea mays L.)* under Semi-Arid Environment. Notulae *Botanicae Horti Agrobotanici Cluj-Napoca, 37*(2), 105-111.

Edwards, D.G., Sharifuddin, H.A.H., Mohd Yusof, M.N., Grundon, N.J., Shamshuddin, J. & Norhayati, M. (1991). The management of soil acidity for sustainable crop production. In. Plant. Soil interaction at low pH, eds. R.J.Wright, V.C. Baligar, and R.P. Murrmann. Kluwer Academic publication. Dordrecht. Pp: 383-396

El-Hendawy, S., Hokam, E., & Schmidhalter, U. (2008a). Drip irrigation frequency: The effects and their interaction with nitrogen fertilization on sandy soil water distribution, maize yield and water use efficiency under Egyptian conditions. *Journal of Agronomy and Crop Science, 194*(3), 180-192.

El-Hendawy, S. E., El-Lattief, E. A. A., Ahmed, M. S., & Schmidhalter, U. (2008b). Irrigation rate and plant density effects on yield and water use efficiency of drip-irrigated corn. *Agricultural Water Management, 95*(7), 836-844.

Eshghizadehb, A. H. K. H. R. (2011). Yield Response of Corn to Single and Combined Application of Cattle Manure and Urea. *Communications in soil science and plant analysis*, *42*(10), 1200-1208.

Ewulo, B. (2005). Effect of poultry dung and cattle manure on chemical properties of clay and sandy clay loam soil. *Journal of Animal and Veterinary Advances*, *4*, 839-841.

FAO. (2012). Statistical data. Food and Agricultural Organization, Rome. (Online) ;http://faostat.fao.org/faostat(sited on 23/02/13).

FAO.(1988). Irrigation water management: Irrigaton methods (Online) http://www.fao.org/docrep/S8684E/S8684E00.htm (sited on 29/03/13)

Farsiani, A., Ghobadi, M. E., & Jalali-Honarmand, S. (2011). The effect of water deficit and sowing date on yield components and seed sugar contents of sweet corn (*Zea mays L.). African Journal of Agricultural Research*, *6*(26), 5769-5774.

Farré, I., & Faci, J. M. (2009). Deficit irrigation in maize for reducing agricultural water use in a Mediterranean environment. Agricultural *Water Management*,*96*(3), 383-394.

Fletcher, A. L., Moot, D. J., & Stone, P. J. (2008). Solar radiation interception and canopy expansion of sweet corn in response to phosphorus. *European journal of agronomy*, *29*(2), 80-87.

Forouzani, M., Karami, E., Zibaei, M., & Zamani, G. H. (2012). Agricultural Water Poverty Index for a Sustainable World. *Farming for Food and Water Security*, 127-155.

Gaffarzadeh, M., Prechac, F.G., & Cruse, R.M. (1998). Fertilizer and soil nitrogen use byCorn and border crops in a strip intercropping system. *Agronomy Journal* 90:758-762.

Garcia y Garcia, A., Guerra, L. C., & Hoogenboom, G. (2009). Water use and water use efficiency of sweet corn under different weather conditions and soil moisture regimes. *Agricultural Water Management*, *96*(10), 1369-1376.

Geerts, S., & Raes, D. (2009). Deficit irrigation as an on-farm strategy to maximize crop water productivity in dry areas. *Agricultural Water Management*, *96*(9), 1275-1284.

Gichangi, E. M., Mnkeni, P. N. S., & Brookes, P. C. (2010). Goat manure application improves phosphate fertilizer effectiveness through enhanced biological cycling of phosphorus. *Soil Science and Plant Nutrition*, *56*(6), 853-860.

Gichangi, E., & Mnkeni, P. (2009). Effects of goat manure and lime addition on phosphate sorption by two soils from the Transkei region, South Africa. *Communications in soil science and plant analysis*, *40*(21-22), 3335-3347.

Gil, M., Carballo, M., & Calvo, L. (2008). Fertilization of maize with compost from cattle manure supplemented with additional mineral nutrients. *Waste management*, 28(8), 1432-1440.

Gutierrez-Miceli, F., Moguel-Zamudio, B., Abud-Archila, M., Gutierrez-Oliva, V., & Dendooven, L. (2008). Sheep manure vermicompost supplemented with a native diazotrophic bacteria and mycorrhizas for maize cultivation. *Bioresource technology, 99*(15), 7020-7026.

Halvorson, A.F.B.A. (2011). Manure and nitrogen fertilizer effects on corn productivity and soil fertility under drip and furrow irrigation. *Archives of Agronomy and Soil science.*, 1-19.

Hartemink, A. E. (2006). Soil fertility decline: definitions and assessment. *Encyclopedia of Soil Science*, 1618-1621.

Hassanli, A. M., Ebrahimizadeh, M. A., & Beecham, S. (2009). The effects of irrigation methods with effluent and irrigation scheduling on water use efficiency and corn yields in an arid region. *Agricultural Water Management, 96*(1), 93-99.

Herencia, J.F., Ruiz-Porras, J.C., Melero, S., Garcia-Galavis, P.A., Morillo E., & Maqueda, C. (2007). Comparison between organic and mineral fertilization for soil fertility levels, crop macronutrient concentrations and yield. *Agronomy Journal*, 99: 973-983.

IPES. (2005). Lesson 30: Nutrient management, land application and nutrient management (MODULE D)

Islam, M. R., Hu, Y., Mao, S., Jia, P., Eneji, A. E., & Xue, X. (2011). Effects of water-saving superabsorbent polymer on antioxidant enzyme activities and lipid peroxidation in corn (*Zea mays L.*) under drought stress. *Journal of the Science of Food and Agriculture, 91*(5), 813-819.

Jaliya, M., Falaki, A., Mahmud, M., & Sani, Y. (2008). Effect of sowing date and NPK fertilizer rate on yield and yield components of quality protein maize (*Zea mays L.*). *Journal of Agricultural and Biological Science, 3*(2), 23-29.

Kara, T., & Biber, C. (2008). Irrigation frequencies and corn (*Zea mays L.)* yield relation in Northern Turkey. *Pakistan Journal of Biological Sciences, 11*(1), 123-126.

Kirda, C. (2002). Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. *Irrigation Science*, 3-10.

Kogbe, J., & Adediran, J. (2003). Influence of nitrogen, phosphorus and potassium application on the yield of maize in the savanna zone of Nigeria. *African Journal of Biotechnology, 2*(10), 345-349.

Kolawole Edomwonyi, L. A. W. O., & Remison, S. U. (2009). Growth and Yield of Maize as Influenced by Sowing Date and Poultry Manure Application. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 37.

Lamm, F. R., & Aiken, R. M. (2005). Effect of irrigation frequency for limited subsurface drip irrigation of corn. Paper presented at the Proc. Irrigation Assn. Int'l. *Irrigation Technical Conference, November*.

Lascano, R. J., Sojka, R. E., Adamsen, F., Agronomy, A. S. O., America, C. S. S. o., & America, S. S. S. O. (2007). *Irrigation of agricultural crops*: American Society of Agronomy.

Lawrence, C. J., Harper, L. C., Schaeffer, M. L., Sen, T. Z., Seigfried, T. E., & Campbell, D. A. (2008). Maize GDB: the maize model organism database for basic, translational, and applied research. *International journal of plant genomics, 2008*.

Lehrsch, G. A., & Kincaid, D. (2007). Compost and manure effects on fertilized corn silage yield and nitrogen uptake under irrigation. *Communications in soil science and plant analysis, 38*(15-16), 2131-2147.

Liang, B., & MacKenzie, A. (1994). Corn yield, nitrogen uptake and nitrogen use efficiency as influenced by nitrogen fertilization. *Canadian journal of soil science, 74*(2), 235-240.

Liu, K., Ma, B., Luan, L., & Li, C. (2011). Nitrogen, Phosphorus, and Potassium nutrient effects on grain filling and yield of high-yielding summer corn. *Journal of Plant Nutrition, 34*(10), 1516-1531.

Mallarino, A. P., Sawyer, J., & Kaiser, D. E. (2010). Utilization of poultry manure phosphorus for corn production. *Soil Science Society of America Journal, 74*(6), 2211-2222.

Malvi, U. R. (2011). Interaction of micronutrients with major nutrients with special reference to potassium. *Karnataka Journal of Agricultural Sciences, 24*(1).

Maqbool, A.. & Silva, J.A. (1998). Growth behavior and contents of sweet corn affected by nitrogen application and intercropping. *Pakistan Journal of Soil Science,* 15: 130-134.

Materechera, S.A., & Salagae, A.M. (2002). Use of partially-decomposed cattle and chicken manure amended with wood-ash in two South African arable soils with contrasting texture: effect on nutrient uptake, early growth and dry matter yield of maize. *Communications in Soil science and Plant Analysis,* (33), 179-201.

Miao, Y., Mulla, D.J., Hennandez, J.A., Wiebers, M., & Robert, P.C. (2007). Potential impact of precission nitrogen management on corn yeid, protein conten, and test weight. *Soil Science Society of America Journal*, 71.:1490-1499.

Moser, SB., Feil, B., Jampatong, S., & Stamp, P. (2006). Effect of pre-anthesis drought nitrogen fertilizer rate and variety on grain yield, yield components and harvest index of tropical maize. *Agriculture Water Management.* 81: 41-58.

Nahm, K. (2003). Evaluation of the nitrogen content in poultry manure. *World's Poultry Science Journal*, 59(1), 77-88.

N'Dayegamiye, A., Laverdière, M. R., Nyiraneza, J., & Chantigny, M. H. (2009). Dairy cattle manure improves soil productivity in low residue rotation systems. *Agronomy Journal, 101*(1), 207-214.

NeSmith, D.S., & Ritchie, J.T. (1992). Short- and long-term responses of corn to a pre-anthesis soil water deficit. *Agronomy Journal*, 84, 107–113.

Oad, F., Buriro, U., & Agha, S. (2004). Effectof organic and inorganic fertilizer application on maize fodder production. *Asian Journal of Plant Science, 3*(3), 375-377.

Ojeniyi, S.O. (2000). Effect of goat manure on soil nutrients content and okra yield in rainforest are of Nigeria. *Applied Tropical Agriculture*, 5:20-23.

Ojeniyi, S.O., & Adejobi, K.B. (2002). Effect of ash and goat dung manure on leaf nutrients composition, growth and yield of amarathus. *Nigerian Agricultural journal* 33:46-57.

Oktem, A. (2008). Effect of water shortage on yield and protein and mineral compositions of drip- irrigated sweet corn in sustainable agricultural systems. *Agricultural Water Management, 95: 1003-1010.*

Oktem, A.G., & Oktem, A. (2005). Effect of nitrogen and intra row spaces on sweet corn (*Zea mays saccharataSturt*) ear characteristics. *Asian Journal of Plant Science*, 4:361-364.

Oktem, A., Simsek, M., & Oktem, A. G. (2003). Deficit irrigation effects on sweet corn (*Zea mays saccharataSturt*) with drip irrigation system in a semi-arid region:: I. Water-yield relationship. *Agricultural Water Management*, 61(1), 63-74. Pp: 48.

Osborne, SL., Schepers, JS., Francis, D.D., & Schlemer, M.R. (2002). Use of spectral radiance to estimate in- season biomass and grain yield in nitrogen and water-stressed corn. *Crop Science*, 42: 165-171.

Pandey, R. K., Maranville, J. W., & Admou, A. (2000). Deficit irrigation and nitrogen effects on maize in a Sahelian environment: I. Grain yield and yield components. *Agricultural Water Management*, *46*(1), 1-13.

Paramanantahn, S. & Lim, C.P. (1979). Oxisols of Malaysia. In: proc. Second interational Soil Classification Workshop: 1. Malaysia. F.H.Beinroth and S. Paramathan (eds). Soil Survey Division, Land Development Department, Bangkok. Pp: 95-111.

Phene, C.J., Davis, K.R., Hutchmaker, R.B., Bar-Yosef, B., Meek, D.W., & Misaki J. (1991). Effect of high frequency surface and subsurface drip irrigation on root distribution of sweet corn. *Irrigation Science* 12, 135-140.

Pidwirny, M.j. (Ed.). (2002). Fundamentals of physical Geography. *(2end Edition ed.).* British Columbia .Canada.

Piekielek, W.P., & Fox, R.H. (1992). Use of a chlorophyll meter to predict side dress nitrogen requirements for maize. *Agronomy Journal*, 84: 59–65.

Rawlins, S., & Raats, P. (1975). Prospects for high-frequency irrigation. *Science, 188*(4188), 604-610.

Remison, S. U. (2005). Arable and vegetable crops. Gift-Press Associates, Benin City.

Richards, L.A. (1947). Pressure membrane apparatus- construction and use. *Agriculture Engineering*, 28:451-454.

Rivera-Hernández, B., Carrillo-Ávila, E., Obrador-Olán, J. J., Juárez-López, J. F., Aceves-Navarro, L. A., & García-López, E. (2009). Soil moisture tension and phosphate fertilization on yield components of A-7573 sweet corn (< i> Zea mays</i> L.) hybrid, in Campeche, Mexico. *Agricultural water management,96*(9), 1285-1292.

Saeed, I., Abbasi, M.k., & Kazmi, M. (2001). Response of maize (Zea mays L.) to NP Fertilization under Agro-climatic Conditions of Rawalakot Azad Jammu and Kashmir. *Pakistan Journal of Biological Science 4 (8): 949-952.*

Sadler, E.J., Bauer, P.J., Busscher, W.J., & Millen, J.A. (2000). Sitespecific analysis of a droughted corn crop: Part II. *Water use and stress. Agronomy Journal*. 92, 403–410.

Salemi, H., Soom, M. A. M., Lee, T. S., Yusoff, M. K., & Ahmad, D. (2011). Effects of Deficit Irrigation on Water Productivity and Maize Yields in Arid Regions of Iran. *Pertanika Journal Tropical Agricultural Science, 34*(2), 207-216.

Salvador, R.J., & Pearce, R.B. (1995). Proposed standard system of nomenclature for maize grain filling events and concepts. *Maydica* 40, 141–146.

Sammis, T. W., Kratky, B. A., & Wu, I. P. (1988). Effects of limited irrigation on lettuce and chinese cabbage yields. *Irrigation Science, 9*(3), 187-198.

Shamshuddin, J & Che Fauziah, I. (2010). Weathered Tropical Soils: The Ultisols and Oxisols. UPM Press, Serdang.

Shamshuddin, J., CheFauziah, I., & Sharifuddin, H.A.H. (1991). Effects of limestone and gypsum applications to a Malaysian Ultisol on soil solution composition and yields of maize and groundnut. *Plant and Soil.* 134: 45-52.

Sharifuddin, H.A.H., & Dynoodt, R.F.P. (1981). Basic guide to soil and plant analysis. Soil Science Department. Technical Bulletin, Faculty of Agriculture, UPM, Serdang.

Sheaffer, C. (Ed.). (2009). Introduction to agronomy. Clfton park,NY:Delmar cengage learning 2009.

Shokri., (2002). *Effects of sheep manure application on the production of dwarf napier grass*. Msc thesis, University Putra Malaysia.

Shultz, S. (2008). Corn,Commodity of the Quarter. *Journal of Agriculture and food information,* 9(2), 101-114.

Sinclair T.R., Bingham, G.E., Lemon, E.R. & Allen, J.R. (1990). Water use efficiency of field grown maize during water stress. *Plant Physiology* 56, 245-249.

Sistani, K., Sikora, F., & Rasnake, M. (2008). Poultry litter and tillage influences on corn production and soil nutrients in a Kentucky silt loam soil. *Soil and Tillage Research, 98*(2), 130-139.

Soil Survey Staff, (1999). Keys to soil Taxonomy. United States Department of Agriculture. Washington DC.

Stone, P.J., Wilson, DR., Reid, J.B, & Gillespie, R.N. (2001). Water deficit effects on sweet corn. I. Water use, radiation use efficiency growth and yield. *Australian Journal of Agriculture and resource*, 52(1): 103-113.

Tahir Mahmood, M. M., Tahir Hussain Awan & Rashid Sarwar. (2001). Effect of different levels of Nitrogen and Intra-row plant spacing on yield and yield components of Maize. *Pakistan Journal of Sciences, 38*(1-2), 48-49.

Tessens, E., & Shamshuddin, J. (1983). Quantitative Relationship between Mineralogy and Properties of Tropical Soils. Serdang: UPM press.

Teh, C.B.S & Jamal,T. (2006). Soil Physics Analysis. Serdang: UPM press.

Traore, S.B., Carlson, R.E. Pilcher, C.D. & Gillespie, G.N. (2000). Bt and non Bt maize growth and development as affected by temperature and drought stress. *Agronomy Journal 92, 1027-1035.*

Trindade, H., Coutinho, J., Jarvis, S. & Moreira, N. (2001). Nitrogen mineralization in sandy loam soils under an intensive double cropping system with dairy cattle Slurry applications. *European journal of Agronomy* 15, 281-293

Unruh, J. D. (1991). Nomadic pastoralism and irrigated agriculture in Somalia. *GeoJournal,* 25(1), 91-108.

Van den Boogaard, R.de Boer, M., Veneklaas, E.J, & lambers, H. (1996). Relative grwoth rate, biomass allocation pattern and water uses of three wheat cultivars during early ontogeny as dependent on water availability.*Phsiologia Plantarum.* 98: 493-504.

Vetsch, J. A., & Randall, G. W. (2004). Corn production as affected by nitrogen application timing and tillage. *Agronomy Journal*, 96(2), 502-509.

Vories, E., Tacker, P., Lancaster, S., & Glover, R. (2009). Subsurface drip irrigation of corn in the United States Mid-South. *Agricultural Water Management,* 96(6), 912-916.

Wolf, B. (1982). A comprehensive system of leaf analysis and its use for diagnosing crop nutrient status. *Communication in Soil Science and Plant Analysis* 18:131-147.

Wrigly, G. (1981). Tropical agriculture. The development of production. (Fifth edition). Long man Pteltd (Singapore)