UNIVERSITI PUTRA MALAYSIA

SWEET CORN (ZEA MAYS L.) SEED GERMINATION AND PRODUCTION UNDER WATER AND NITROGEN DEFICIT UNDER GLASSHOUSE CONDITIONS

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By

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

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DEDICATION

I dedicate this thesis to my beloved family,

*especially my **wife** and*

My children

*(**Pooya** and **Mohammad Hosein**)*

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

SWEET CORN (*ZEA MAYS* L.) SEED GERMINATON AND PRODUCTION UNDER WATER AND NITROGEN DEFICITUNDER GLASSHOUSE CONDITIONS

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May 2013

Chairman: Associate Professor Adam B. Puteh, PhD

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Water and nitrogen deficits limit plant performance and subsequently reduce the yield potential in corn. The effect of osmotic potentials (MPa) on sweet corn was evaluated during seed germination in the laboratory and the effects of water and different nitrogen rates were evaluated under field conditions. Seeds of eight sweet corn varieties (Hybrid 968, Hybrid 969, Hybrid 926, Hybrid 8800, Hybrid 3922, Hybrid 2328, Masmadu and Thai Super Sweet) were germinated in Petri dishes containing polyethylene glycol (PEG) at concentrations equivalent to -0.2, -0.5, -0.7, -1.2 and -1.4 MPa osmotic potential. The results showed that proline content in the seedling and mean germination time increased with increasing osmotic potential. However, germination percentage (GP), germination index (GI), coefficient of velocity of germination (CVG), root length (RL) and root diameter (RD) were reduced with increasing osmotic potential. Two hybrids of sweet corn, hybrid 968 and 926, were subsequently planted under rain shelter and water deficits were imposed at vegetative, tasseling and both at vegetative and tasseling stages, with nitrogen rates at 40, 120 and 200 kg ha^{-1}. The reproductive growth stage was more sensitive to water deficit and reduced nitrogen rates compared with the vegetative growth stage for all varieties. Water and nitrogen deficit during vegetative and reproductive growth stages reduced ear size (ES), kernel weight per ear (KWE), number of kernel per ear (NKE) and 1000 -kernel weight (1000-KW). The number of rows per ear (RE) was affected under nitrogen deficit. Water deficit and nitrogen rates of less than200 kg/ha, at both vegetative and reproductive stages, reduced plant height, number of leaves, leaf area index (LAI), crop growth rate (CGR), chlorophyll content and dry matter. Relative water content, photosynthesis rate and stomatal conductivity values were significantly influenced under water deficit and nitrogen deficit. Pollen number was reduced when plants were imposed to water and nitrogen deficit. However, pollen viability was only affected under water deficit. Water deficit for short periods did not affect shoot nitrogen concentration, but nitrogen concentration in shoot was reduced under nitrogen deficit. The study indicated that proline content in seedling was increased when germination occur at low osmotic potentials. Ear weight m^{-2} under adequate moisture conditions needs higher nitrogen to produce optimum yield than under stress conditions. Therefore, sweet corn varieties under vegetative drought require 120 kg $ha^{-1}$of applied nitrogen to obtain optimum seed yield.

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

PERCAMBAHAN DAN PENGELUARAN BIJI BENIH JAGONG MANIS (*ZEA MAYS* L.) PADA KEADAAN DEFICIT AIR DAN NITROGEN DALAM RUMAH KACA

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Kekurangan air dan nitrogen berpotensi mengurangkan hasil untuk tanaman jagung. Kesan osmotik (MPa) pada jagung manis telah dinilai semasa percambahan benih di makmal dan kesan air serta kadar nitrogen yang berbeza telah dinilai di lapangan. Lapan varieti benih jagung manis (Hybrid968, Hybrid969, Hybrid926, Hybrid8800, Hybrid3922, Hibrid 2328, Masmadu dan Thai super manis) dicambah di dalam Petri yang mengandungi polietilen glikol (PEG) pada kepekatan-0.2, -0.5, -0.7, -1.2 dan -1.4 potensi osmosis (Mpa). Keputusan menunjukkan bahawa kandungan prolin dalam anak benih dan min masa percambahan (MGT) meningkat dengan peningkatan potensi osmosis. Walau

bagaimanapun, peratusan percambahan (GP), indeks percambahan (GI), pekali halaju percambahan (CVG), panjang akar (RL) dan diameter akar (RD) telah berkurangandisebabkan olehpeningkatan potensi osmotik (MPa). Dua hibrid (hibrid 968 dan 926) telah ditanam dalam beg polietilen di tempat perlindungan hujan dan defisit air telah dilakukan pada peringkat vegetatif, berbunga dan atau kedua-duanya dengan kadar nitrogen pada 40, 120 dan 200 kg ha^{-1}. Defisit air dan nitrogen dilaksanakan semasa peringkat pertumbuhan vegetatif dan pembiakan. Saiz Ear (ES), berat kernel satu Ear (KWE), jumlah kernel satu tongkol (NKE) dan 1000 - kernel berat (1000-KW) telah diukur. Hasil pemerhatian didapati setiap tongkol (RE) telah terjejas pada defisit nitrogen. Bagi defisit air dan defisit nitroge, peringkat reproduktif lebih sensitif daripada peringkat vegetatif. Defisit air dan kadar defisit nitrogen pada 200 kg ha^{-1}, peringkat vegetatif dan pembiakan, mengurangkan ketinggian pokok, bilangan daun, LAI, CGR, kandungan klorofil dan bahan kering. Kandungan air relatif, kadar fotosintesis dan nilai-nilai konduktan stomata sangat dipengaruhi di bawah defisit air dan defisit nitrogen. Bilangan debunga berkurangan apabila percambahan dikenakan defisit air dan nitrogen. Walau bagaimanapun, daya maju debunga hanya terjejas di bawah defisit air. Didapati juga defisit air bagi tempoh yang singkat tidak mempengaruhi kandungan nitrogen pada pucuk tetapi kepekatan nitrogen dalam pucuk berkurangan di bawah defisit nitrogen. Kajian menunjukkan bahawa kandungan proline bagi anak benih telah meningkat apabila percambahan berlaku pada potensi osmosis rendah . Kadar Fotosintesis, jumlahdebunga dan nilai-nilai konduktan stomata berkurangandalam air dan defisit nitrogen. Berat Ear setiap m^2 dalam keadaan lembap yang mencukupi memerlukan nitrogen yang tinggi untuk mengeluarkan hasil yang optimum berbandingdengan keadaan stres. Oleh itu, varieti jagung manis bawah vegetatif drought (VD) 120 kg ha^{-1} nitrogen gunaan adalah memadai.

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I certify that a Thesis Examination Committee has met on (31 May 2013) to conduct the final examination of Ali Shahriari on his thesis entitled "**Sweet Corn (*Zea Mays* L.) Seed Germination and Production under Water and Nitrogen Deficit under Glasshouse Conditions**" 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.

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institutions.

ALI SHAHRIARI

Date: 31 May 2013

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LIST OF ABBREVIATIONS

MPa	Mega Pascal
OP	Osmotic potential
PEG	Polyethylene glycol
GP	Germination percentage
MGT	Mean germination time
CVG	Coefficient velocity of germination
GI	Germination index
RL	Root length
RD	Root diameter
EWm^{-2}	Ear weight m^{-2}
RE	Rows per ear
ES	Ear size
KWE	Kernel weight per ear
NKE	Number of kernel per ear
1000-KW	1000- Kernel weight
DAP	Days after planting
CGR	Crop growth ratio
RWC	Relative water content
NL	Number of leaves
PH	Plant height
DM	Dry matter
VD	Vegetative drought
TD	Tasseling drought

(V+T)D	Vegetative and tasseling drought
LAI	Leaf area index
H	Hybrid
SE	Standard error
IKI	Iodine potassium iodide
mL	milliliters

CHAPTER 1

INTRODUCTION

Maize (*Zea mays* L.) is one of the main agricultural crops in the family Poaceae, which is ranked as the third important crop after wheat and rice. Due to its high adaptability, it is well distributed and highly productive in most cultivable agricultural lands in the world. It produces high total dry matter and the grain contains various nutritious substances such as carbohydrates, proteins and edible oil.

Containing 8-15% protein, this plant is considered as a main source of protein, essential for cell growth in human. Apart from pharmaceutical and nutritional applications, maize is also a good source for fuel and feedstock worldwide. It is annually grown as food and as industrial raw material for the production of oil, starch, sugar, syrups and other uses.

According to the United States Department of Agriculture-Foreign Agricultural Services (USDA-FAS, 2010), with the rapid growth in world population, the demand for this product will increase. Based on statistics, corn production increased from 713000 (MT) in 2006 to 835000 (MT) in 2010. The major corn producers are the United States, China, Brazil and Argentina. In Malaysia, corn production increased from 80000 metric tons in 2006 to 95000 metric tons in 2010 (USDA-FAS, 2010).

Agricultural research has been traditionally focused on maximizing yield increases worldwide. However, more attention is now given to the availability of land and water, which appear to be the main limiting factors of production. Consequently, water deficit has recently been experimented as a new strategy in dry regions facing lack of water for crop production(English, 1990; Fereres and Soriano, 2007; Pereira *et al.*, 2002).

As arid and semi-arid lands are naturally under the threat of drought, crop yields are prone to drastic reduction in such areas. This is also the case with lands where the soil has a limited supply of water due to high evapo-transpiration. Presently, in most places on earth, the natural water supply used for irrigation is declining. The prospects for water shortage are explicable in terms of climate changes with temperature increases and shortage of rainfall. Given such circumstances, it is crucial to investigate crop responses to water shortages in specific environments so that appropriate irrigation deficit strategies can be employed for watering plants and improving irrigation efficiency. In this strategy, we can reduce water irrigation for one or two time without significant reducing in production.

In general, crop production requires appropriate amounts of nitrogen and water. As for maize, production is optimized with balanced amounts of these two factors. Hence, water shortage and exhaustive nitrogen use research on yield potential are important issues in maize production. At water deficit, nitrogen rate reduced for reach to maximum crop production.

Proper crop and soil management systems including water conservation, irrigation and water management and fertilizer application can mitigate water shortages, increase productivity and reduce environmental pollution (Herrero *et al.*,2007). Crop N status at different growth stages and the supply of sufficient amounts of N fertilizer require careful investigation. Better yields and more efficient N-use can be achieved with lowest N losses into the environment (Zhao *et al.*, 2003).

Decreasing osmotic potential reduced seedling growth under PEG solution in *lentil culinaris* (Haq*et al.*2010).Tolerant corn to water deficit controlled by genotypes. Tolerance trait to water stress related to water deficit severity and controlled by some morphological and physiological process (Aslam *et al.* 2006).

Hence, the present study was designed with the main objectives, best time for shortage irrigation deficit, different nitrogen rates and investigating the interaction of production factors on different varieties of sweet corn.

The specific objectives of this thesis were to:

i) Determine germination behavior and proline accumulation in sweet corn seedlings in response to different osmotic potential conditions generated using polyethylene glycol.

ii) Evaluate the effects of water and nitrogen deficits on the morphological and physiological parameters of sweet corn.

iii) Evaluate the effects of water and nitrogen deficits at different crop growth stages on yield and yield component of sweet corn.

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