UNIVERSITI PUTRA MALAYSIA

IMPACT OF PLANTING DATE AND DENSITY ON GROWTH OF MAIZE IN NORTHERN IRAN

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By

HASSAN MOKHTARPOUR

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

To

My beloved people in my life

My father, my mother, my wife and my lovely daughter Rozhan

Abstract of thesis to be presented to the Senate of University Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

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Chairman: Christopher Teh Boon Sung, PhD

Faculty: Agriculture

Planting date and density are two major factors affecting maize growth and yield. Although many worldwide studies were done to evaluate the effect of planting date and density on maize, it is still necessary to do more studies to add the knowledge in this area because environmental factors affect planting date and density. During the last four decades, many simulation studies were conducted to evaluate maize growth. A robust simulation model can help researchers to understand, predict and control a system. Despite the importance of modeling studies on maize, no simulation study was done in Golestan-Iran. The purpose of this study was to investigate maize growth and yield response to planting date and density in field and simulation studies in Golestan-Iran.

The field studies were conducted at the Agricultural Research Center of Golestan, Iran in 2007 and 2008. In the first experiment, the effects of eight planting dates and

three planting densities (0.16, 4.5, and 6.5 plants m^{-2}) were investigated in 2007. The experiment was replicated in 2008 by adding another planting density (8.5 plants m^{-2}). In the second experiment, maize yield response to a wide range of planting densities (0.16, 2.5, 4.5, 6.5, 8.5, 10.5 and 12.5 plants m^{-2}) was evaluated for two seasons in 2008. In the third study, empirical equations were developed to estimate leaf area and leaf weight using the data from different treatments of the first experiment in 2008. Simulation studies were done using two specific maize models: CERES-Maize and IXIM. To calibrate the models, the data of the first five planting dates in optimum planting densities (6.5 plants m^{-2}) from the first field experiments in 2007 were used. Using stepwise approach and sensitivity analysis, genetic coefficients were calibrated for both models. To evaluate the accuracy of the models, the data from different treatments from the first and second experiments in 2008 were used. The models' validity was tested using three goodness of fit indicators namely, root mean square error, index of agreement (*d*) and mean error.

Results of the first experiment showed planting date, planting density and the interaction between them had significant effect on yield and yield components. The highest yield was produced in the first planting date (10659 kg ha^{-1}). The best planting density among early and middle planting dates was 6.5 plants m^{-2} while for late plantings no significant differences were observed in yield among the different planting densities. Results of the second experiment showed that in the first season the highest yield was observed in planting density 6.5 plants m^{-2} (9470 kg ha^{-1}). However, in the second season, no significant difference in yield was observed among the different planting densities (~4500 kg ha^{-1}). Empirical equations were fitted to the observed data to show the relationship of each of the parameters, yield,

total dry matter (TDM), leaf area index (LAI) and harvest index (HI) to planting density. Results of the third study showed that the empirical equations developed to estimate leaf area, fresh weight and dry weight could predict their values with a high degree of accuracy in different situations. The results of simulation study showed that both CERE-Maize and IXIM models predicted days to anthesis, days to physiological maturity, LAI, and kernel weight with high accuracy in different planting dates and densities although the IXIM showed a better performance comparing to CERES-Maize model. IXIM model simulated TDM, kernel number and yield with higher accuracy comparing to CERES-Maize model in the first five planting dates. However, both models could not give accurate predictions of these traits in the last three planting dates. Evaluating response of CERES-Maize and IXIM models to planting density showed that both models could predict different traits accurately in the middle planting densities (4.5-8.5 m^{-2}). However, both models overestimated most traits in high planting densities (10.5-12.5 plants m^{-2}).

In conclusion, maize should be planted in early planting dates with planting density 6.5 plants m^{-2} in Golestan-Iran. However, to obtain high yield in late planting dates, planting density should be decreased to 4.5 plants m^{-2}. In simulation study, both models could not predict yield and yield component with high accuracy in the late planting dates and high planting densities therefore, it seems some modification are needed to be done in the functions that calculate daily crop growth rate, kernel number m^{-2}, and LAI. These modifications may improve the accuracy of the models to estimate these traits.

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

IMPAK TARIKH PENANAMAN DAN KEPADATAN TANAMAN TERHADAP PERTUMBUHAN JAGUNG DI UTARA IRAN

Oleh

HASSAN MOKHTARPOUR

April 2011

Pengerusi: Christopher Teh Boon Sung, PhD

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Tarikh penanaman dan kepadatan tanaman adalah dua faktor utama yang menpengaruhi pertumbuhan dan hasil jagung. Walaupun terdapat banyak kajian yang giat dijalankan untuk mengkaji kesan tarikh penanaman dan kepadatan tanaman bagi jagung, namun adalah amat penting untuk mendalami kajian kerana faktor alam sekitar sangat mempengaruhi. Selama empat dekat yang lalu, banyak kajian simulasi telah dijalankan untuk mengkaji pertumbuhan jagung. Model yang tepat boleh membantu para penyelidik untuk memahami, meramal, dan mengawal sesebuah sistem. Walaupun kajian ini penting, namun tiada kajian simulasi telah dilakukan di Golestan-Iran. Kajian lapangan ini melibatkan tiga eksperimen yang telah dijalankan di Pusat Penyelidikan Pertanian Golestan-Iran pada tahun 2007 dan 2008. Untuk eksperimen pertama, kesan untuk lapan tarikh tanaman dan tiga kepadatan tanaman (0.16, 4.5, dan 6.5 pokok m^{-2}) dikaji pada tahun 2007. Eksperimen ini diulangi pada tahun 2008 dengan menambah satu lagi kepadatan tanaman (8.5 pokok m^{-2}). Untuk eksperimen kedua, tindakbalas hasil tuai jagung untuk kepadatan tanaman yang

lebih banyak (0.16, 2.5, 4.5, 8.5, dan 12.5 pokok per m^{-2}) telah dikaji dalam dua musim pada tahun 2008. Untuk eksperimen ketiga, persamaan empirikal telah dibangunkan untuk mengganggar keluasan daun dan berat daun dengan mengunakan data yang diperolehi daripada rawatan pada eksperimen pertama pada tahun 2008.

Kajian simulasi telah dijalankan dengan menggunakan dua model spesifik untuk tanaman jagung iaitu CERES-Maize dan IXIM. Untuk menguji model, data untuk lima traikh tanaman pertama bagi kepadatan tanaman yang optimum (6.5 pokok m^{-2}) untuk eksperimen pertama pada tahun 2007 telah digunakan. Dengan menggunakan kaedah *stepwise* dan analisis sensitivity, koefisien genetic telah dikalibrasi untuk kedua-dua model. Untuk mengenalpasti ketepatan model, data daripada eksperimen pertama dan eksperimen kedua telah digunakan. Kesahihan model telah diuji dengan menggunakan 3 penunjuk: *roots mean square error*, indeks kesamaan (*d*) dan purata ralat. Hasil daripada eksperimen pertama menunjukkan tarikh tanaman, kepadatan tanaman dan interaksi dintara hasil tuai, tarikh tanaman dan kepadatan tanaman menunjukkan kesan yang nyata.

Hasil tuai tertinggi dicatatkan pada tarikh terawal tanaman (10659 kg ha^{-1}). Kepadatan tanaman yang paling baik untuk tarikh tanaman awal dan pertengahan adalah 6.5 pokok m^{-2} sementara untuk tarikh akhiran tanaman tidak menunjukkan perbezaan yang ketara untuk kepadatan tanaman yang berbeza. Eksperimen kedua menunjukkan bahawa pada musim pertama, hasil tuai yang teringgi dicatatkan untuk kepadatan tanaman 6.5 pokok m^{-2} (9470kg ha^{-1}). Walau bagaimanapun, untuk musim kedua, tiada perbezaan ketara dicatatkan untuk kepadatan tanaman yang berbeza (~4500 kg ha^{-1}). Persamaan empirikal telah digunakan untuk mengetahui hubungan

diantara kepadatan tanaman, hasil tuai, jumlah berat kering (TDM), indek keluasan daun (LAI), dan index tuaian (HI).Untuk eksperimen ketiga, keputusan menunjukkan bahawa persamaan yang dibangunkan untuk mengira luas daun, berat daun dan berat kering daun dapat digunakan untuk meramal nilai yang lebih tepat. Hasil dari simulasi, kedua-dua model CEREZ- Maize dan IXIM boleh meramal sehingga dari hari pengeluaran bunga jagung, hari sehingga kematangan fizikal jagung, LAI dan berat biji jagung dengan ketepatan yang tinggi untuk kepadatan tanaman yang berbeza dimana IXIM lebih menunjukkan pretasi cemerlang berbanding CERES-maize dalam lima kepadatan tarikh tanaman pertama. Walau bagaimanapun, kedua-dua model tidak dapat menganggar simulasi hasil tuai yang baik untuk tiga tarikh penanaman yang terakhir. Evaluasi tindakbalas model menggunakan CERES-maize dan IXIM terhadap tarikh penanaman menunjukkan kedua-dua model tidak dapat meramal kesan yang lebih tepat untuk kepadatan tanaman sederhana (4.5-8.5 pokok m^{-2}). Namun, untuk kepadatan tanaman yang lebih tinggi (10.5-12.5 m^{-2}) model telah terlebih anggaran.

Sebagai kesimpulannya, jagung harus ditanam pada tarikh tanaman yang awal dengan kepadatan tanaman 6.5 pokok m^{-2} di Golestan, Iran. Untuk mencapai hasil tuai yang tinggi, pada tarikh tanaman yang kemudian, kepadatan tanaman seharusnya dikurangkan sehingga 4.5 pokok m^{-2}. Dalam kajian simulasi, kedua-dua model tidak dapat meramal hasil tuai dan komponen tuaian dengan ketepatan tinggi dan oleh itu beberapa modifikasi perlu dilakukan dalam fungsi yang mengira kadar pertumbuhan harian, bilangan biji benih dan LAI. Modifikasi ini perlu untuk meramal dengan lebih tepat.

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Hassan Mokhtarpour

UPM, Malaysia, April 2011

I certify that an Examination Committee met on 1 April of 2011 to conduct the final examination of Hassan Mokhtarpour on his doctor of philosophy thesis entitled "Experimental and Modeling Studies to Determine the Impact of Planting Date and Plant Density on Growth of Maize in Northern Iran" in accordance with Universities and University College Act 1971 and the Constitution of Universiti Putra Malaysia [P.U.(A) 106] 15 march 1998. The Committee recommends that the student be awarded the relevant degree.

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

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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.

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HASSAN MOKHTARPOUR

Date: 1 April 2011

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