EFFECTS OF DIFFERENT TILLAGE SYSTEMS AND PLANTING DENSITIES ON SOIL PHYSICAL PROPERTIES AND YIELD COMPONENTS OF SWEET CORN (ZEA MAYS L.)

HOSSEINALI TASH SHAMSABADI

FK 2011 13
EFFECTS OF DIFFERENT TILLAGE SYSTEMS AND PLANTING DENSITIES ON SOIL PHYSICAL PROPERTIES AND YIELD COMPONENTS OF SWEET CORN (ZEA MAYS L.)

By

HOSSEINALI TASH SHAMSABADI

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

March 2011
Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of
the requirement for the degree of Doctor of Philosophy

EFFECTS OF DIFFERENT TILLAGE SYSTEMS AND PLANTING DENSITIES
ON SOIL PHYSICAL PROPERTIES AND YIELD COMPONENTS OF SWEET
CORN (ZEA MAYS L.)

By
HOSSEINALI TASH SHAMSABADI
March 2011

Chairman: Professor Desa Ahmad, PhD, P. Eng.

Faculty: Engineering

Sweet corn or maize (Zea mays L.) is the world’s most important crops after wheat,
barley and rice. This plant is nutritionally superior to other cereals in many ways, except
in protein value. Considering the limitation of production resources and the increasing
world population, efforts should be made to increase productivity of crop. Among the
factors that influence corn productivity are planting density and tillage practices. In
Malaysia, the rotary cultivator method which has been the common practice for sweet
corn has some disadvantages and it would be worthwhile to compare it with other tillage
methods. The shallow depth of ploughing and degradation of the soil because of
intensive impact of the rotary blade with the soil has been identified as problems of this
tillage method.
The main objective of this study was to find out the best tillage system or method in terms of soil physical characteristics, and then determining the crop yield of sweet corn as affected by different planting densities. In addition, the most economical tillage system in the field, optimum energy on drawbar power and engine fuel consumption for three tillage methods were also calculated.

Field experiments were conducted over two years (2008 and 2009) to investigate the effects of three tillage systems on selected soil physical properties at two depths of 0-15 and 20-35 cm in the Serdang series soil (*Typic Paleudult*). The research farm was located in the University Putra Malaysia (UPM) in Malaysia. It was under continuous corn planting for several years. The three tillage systems or methods were Moulboard Plough followed by once tandem disc harrowing (MPD), Disc Plough followed by once tandem disc harrowing (DP) and Rotary Cultivator only (RC) as control. Soil physical properties were measured two times, before and after soil tillage and included bulk density dry basis (*BD*_d), total porosity (*P*_t), aggregate size distribution (*Agg*_d≥2mm), mean weight diameter dry basis and wet basis (*MWD*_d and *MWD*_w), water infiltration (*WI*), moisture content volume basis (*MC*_v) and resistance to penetration (*RP*). At the end of the experiment, energy and fuel consumption utilized on the soil ploughed by the tillage systems were calculated.

The results showed that the measured soil physical properties at two depths of the plots (before tillage operation) were homogeneous at three plots and two depths. The highest value of crop yield at any given planting density occurred in MPD plot and decreased in DPD and RC plots, respectively in 2008 and combined two years. This result could be
due to lower BD$_d$ and Agg$_{d2}$2mm, higher MWD$_w$ and P$_t$ in upper layer (0-15 cm) for MPD plot. However WI was higher and RP was lower in RC plot at the same depth. The other reason for sweet corn reduction in RC plot could be higher BD$_d$ and RP at the depth of 20-35 cm that impeded root growth of sweet corn; however MC$_v$ was higher in lower layer. Depth of soil tillage by RC (15 cm) and creation of plough-pan below this depth (plough layer) was the other reason for the lower yield under RC.

Tillage method, planting density and also interaction effects of two factors, tillage and planting density were found to be significant on yield and some yield components of sweet corn such as ear diameter, row length of the kernels on the cob corn, fresh weight of ear con, yield of sweet corn and total weight of dry matter, in 2008. Similarly, all yield parameters except for ear diameter were affected by planting density and interaction of the two factors in 2009. Irrespective of planting density, corn yield was lowest in RC tillage in 2008 and for the combined two years. Crop yield with DPD was 8% higher than RC and with MPD it was 20% higher than RC. Ear diameter, row length of kernel on cob corn and weight of ear were higher at low density compared to high density planting. This could be due to the lower stress or competition between the plants for moisture, nutrients and sunlight under low density planting. Although the stress was higher for the plants with seed spacing of 20 cm; however it did not affect the crop yield and total weight of dry matter at any given tillage methods. This result revealed that there was no deficit of moisture and nutrients for the plants close to each other. Only the limitation of sunlight could be the reason for this finding. Climate or weather condition in 2009 was better than 2008 in terms of greater rainfall and sunshine hour. That is why the yield and some yield components of sweet corn were better in 2009 as compared to
Energy consumption on drawbar power was higher on the soil ploughed with DPD was 56.2 hp and decreased with MPD (52.5 hp) and RC (45.5 hp), respectively whilst fuel consumption was higher on the soil ploughed with MPD (27.02 L) and decreased to 25.69 L with DPD and 18.04 L with RC, respectively. Although energy on drawbar power and engine fuel consumption were higher under MPD and DPD tillage treatments as compared to RC, there was greater benefit gained in MPD plot (20%) and DPD plot (8%) respectively. On the other hand, the highest profit was obtained in MPD plot (RM 21,600) and this decreased to RM 19,500 in DPD plot and RM 18,100 in RC plot, respectively. In general, working condition of two tillage methods (MPD and DPD) was similar in trend in terms of soil physical properties, yield and its components of sweet corn. However, mouldboard plough to a depth of 25 cm followed by one time tandem disc harrowing to a depth of 10 cm with seed spacing of 20 cm showed the best overall results in terms of yield and economic benefit.

**Key Words**: Sweet corn, Mouldboard plough, Disc plough, Rotary cultivator, Soil physical properties, Plant density, Energy and fuel.
Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KESAN SISTEM PEMBAJAKAN BERBEZA DAN KEPADATAN PENANAMAN KE ATAS SIFAT FIZIKAL TANAH DAN KOMPONEN HASIL JAGUNG MANIS

Oleh

HOSSEINALI TASH SHAMSABADI

Mac 2011

Pengerusi: Profesor Desa Ahmad, PhD, P.Eng.

Fakulti: Kejuruteraan


Objektif utama kajian ini adalah untuk menentukan sistem pembajakan terbaik dari aspek ciri fizikal tanah dan hasil optimum dengan kepadatan tanaman berbeza untuk
hasil pengeluaran tanaman jagung manis yang lebih tinggi. Di samping itu, kaedah pembajakan paling ekonomik, tenaga optimum penggunaan kuasa drawbar dan penggunaan bahanapi turut diambil kira.

Bagi mencapai objektif penyelidikan, kajian ladang telah dijalankan untuk tempoh dua tahun (2008 dan 2009) untuk mengkaji kesan tiga jenis sistem atau kaedah pembajakan tanah ke atas sifat fizikal tanah pada kedalaman 0-15 dan 20-35 cm tanah jenis siri Serdang (Typic Paleudult) di ladang penyelidikan Universiti Putra Malaysia Serdang Malaysia. Kawasan tersebut adalah kawasan tanaman jagung untuk beberapa tahun. Kajian ini membandingkan tiga jenis sistem atau kaedah pembajakan tanah tanaman terdiri daripada Bajak Sepak diikuti dengan satu laluan Bajak Harrow Tandem (MPD), Bajak Cakera diikuti dengan satu laluan Bajak Harrow Tandem (DPD) dan Bajak Putar (RC) sebagai kawalan. Ciri fizikal tanah iaitu ketumpatan asas kering (BDd), jumlah keliangan (Pt), taburan saiz aggregat (Aggd>2mm), garis pusat beban min asas kering dan basah (MWDd dan MWDw), penyusupan air (WI), kelembapan asas isipadu (MCv) dan rintangan penusukan (RP) dianalisis dua kali sebelum dan selepas aktiviti pembajakan. Anggaran penggunaan tenaga dan penggunaan bahanapi bagi kawasan yang dibajak turut dikaji.

Keputusan hasil kajian menunjukkan bahawa ciri fizikal tanah pada dua kedalaman sebelum dan selepas pembajakan tidak menunjukkan perubahan yang nyata. Hasil tanaman tertinggi pada semua kepadatan berlaku dalam kawasan MPD dan berkurangan dalam kawasan DPD dengan diikuti oleh kawasan RC pada tahun 2008 serta purata kedua-dua tahun. Ini mungkin berpunca daripada BDd dan AGGd>2mm yang rendah,
MWDw dan Pt yang tinggi di lapisan atas (0-15 mm) bagi kawasan MPD. Walau bagaimanapun nilai WI adalah tinggi dan RP rendah bagi kawasan RC pada kedalaman yang sama. Pengurangan hasil jagung manis dalam kawasan RC berkemungkinan disebabkan oleh nilai BDd dan RP yang tinggi pada kedalaman 20-35 cm yang membantut pertumbuhan akar jagung manis manakala kelembapan MCv adalah tinggi di lapisan bawah. Kewujudan lapisan keras hasil bajakan putar RC juga boleh menjejaskan pertumbuhan akar tanaman tersebut dan mengurangkan hasil tanaman di kawasan RC.

sama lain. Hanya kekurangan cahaya suria yang mungkin menyebabkan pencapaian sedemikian. Cuaca pada tahun 2009 (tahun kedua) adalah lebih baik berbanding tahun 2008 dari aspek jumlah hujan dan tempoh cahaya suria. Ini menyebabkan hasil dan komponen hasil jagung manis pada tahun 2009 lebih baik berbanding tahun 2008 bagi kawasan DPD dan RC. Penggunaan tenaga drawbar pada kawasan DPD adalah 56.2 hp dan menurun pada kawasan MPD (52.5 hp) dan RC (45.5 hp) manakala penggunaan bahanapi adalah tinggi bagi kawasan MPD (27.02 L) dan menurun kepada 25.69 bagi kawasan DPD dan 18.04 L bagi kawasan RC. Walaupun penggunaan tenaga adalah tinggi bagi kawasan MPD dan DPD berbanding RC, lebih banyak faedah diperolehi dalam kawasan MPD iaitu sebanyak 20% dan DPD sebanyak 8%. Keuntungan tertinggi diperolehi dari kawasan MPD (RM21,600) diikuti oleh kawasan DPD (RM19500) dan RM 18,100 bagi kawasan RC.

Secara umumnya, penggunaan kedua-dua kaedah pembajakan (MPD dan DPD) memberikan corak hasil yang sama mengenai sifat fizikal tanah, hasil dan komponen hasil tanaman jagung manis. Walau bagaimanapun penggunaan Bajak Sepak pada kedalaman 25 cm diikuti oleh satu laluan Bajak Harrow Tandem pada kedalaman 10 cm dengan jarak tanaman 20 cm memberikan hasil terbaik keseluruhan dari aspek hasil dan faedah ekonomik.

**Kata kunci:** Jagung manis, Bajak sepak, Bajak cakera, Bajak putar, Ciri fizikal tanah, Kepadatan penanaman, Tenaga dan Bahanapi.
ACKNOWLEDGEMENTS

First and foremost, all praise to Almighty Allah, the most merciful and the Benevolent for His blessings and guidance for giving the author the inspiration to embark on this project and instilling him the strength to see that this dissertation becomes a reality.

In the process of conducting this project at The University Putra Malaysia (UPM), there has been so much support and encouragement which helped this dissertation to be possible.

The author would like to express his sincere gratitude to his supervisor; Prof. Ir. Dr. Desa Ahmad for very strong support through the research work, preparation of this dissertation, generous assistance and patience. Gratitudes are due to Assoc. Prof. Ir. Azmi Yahya and Dr. Jamarei Othman, the members of Supervisory Committee for their valuable suggestions and active guidance. They gave indispensable guidance, as well as encouragement during critical times. A very special gratitude and thanks are due to Dr W. Aimrun, post doctoral candidate in ITMA for valuable guidance and assistance in statistical design; Mr. Hj. Abdol Aziz Abdollah, Technician in Land Management Lab. for help and assistance in experiment carried out in the Lab and sampling from the field. They gave the author their precious times and involvement at several stages of the research. They also helped the author to complete field and laboratory works.

Many thanks are extended to Dr. Ahmad Salamat, from Faculty of Agriculture for useful guidance in procedure and modification of the experimental design; Drs. T. Christopher
and Jamal Talib for permission to use the instruments and apparatus for measurements of soil physical properties.

Special thanks are extended to all staff and operators of TPU, particularly, Mr. Mohammad Tarmizi, coordinator between Department of Biological and Agricultural Engineering and research farm who had devoted interest on experiment in the field and prepared all required materials for doing this research during 2008 and 2009.

The entire Department of Biological and Agricultural Engineering deserves special appreciation. Its strong graduate program is a result of the dedication of many professors, technicians and secretaries.

The author wishes to reveal heartfelt thanks to several Iranian students in Ph.D program and especially Mr. Saberi, Pedram, Mokhtarpoo, Behmaram, Bakhtiar, Moradi and Momayyezi. Acknowledgment is due to Islamic Republic of Iran government for approving a full-time session and for providing the support for study in Malaysia. Many thanks are also due to Gorgan University of Agricultural Sciences and Natural Resources (the author is an academic member in that University) for granting the study leave which enable him to pursue this study.

Finally, the author is forever indebted and is grateful to his wife (Asieh) and children (Fatemeh, Mohammad and Ali) for their patience, sacrifice, sustenance and inspiration at all times. The author’s heartfelt thank to his mother, brothers and sisters for creating moments of endless happiness. He wishes for them health, success and all the best in life. Last but not least he dedicates this work to his late father.
I certify that an Examination Committee has met on Date to conduct the final examination of Hosseinali Tash Shamsabadi on his Doctor of Philosophy thesis entitled “Effects of different tillage systems and planting densities on soil physical properties and yield components of sweet corn (Zea mays L.)” in accordance with Universiti Pertanian Malaysia Act 1980 and Universiti Pertanian Malaysia regulations 1981. The Committee recommends that the student be awarded the (Name of relevant degree).

Members of the Examination Committee were as follows:

Lee Teang Shui  
Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Chairman)

Christopher Teh Boon Sung, Ph.D  
Faculty of Agriculture  
Universiti Putra Malaysia  
(Internal Examiner)

Mohd Ridzwan Abd Halim  
Associate Professor  
Faculty of Agriculture  
Universiti Putra Malaysia  
(Internal Examiner)

Radhey Lal Kushwaha  
Professor  
Canada  
(External Examiner)

SHAMSUDDIN SULAIMAN, PhD  
Professor and Deputy Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date:
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:

**Desa Ahmad, PhD, P. Eng.**  
Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Chairman)

**Azmi Yahya, PhD, P. Eng.**  
Associate Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Member)

**Jamarei Othman, PhD**  
Senior Lecturer  
Faculty of Engineering  
Universiti Putra Malaysia  
(Member)

---

**HASANAH MOHD GHAZALI, PhD**  
Professor and Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date:

xiii
DECLARATION

I hereby 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 institution.

HOSSEINALI TASH SHAMSABADI

Date: 3 March 2011
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>ABSTRACT</th>
<th>ii</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRAK</td>
<td>vi</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>x</td>
</tr>
<tr>
<td>APPROVAL</td>
<td>xii</td>
</tr>
<tr>
<td>DECLARATION</td>
<td>xiv</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xviii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xx</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>xxvii</td>
</tr>
</tbody>
</table>

## CHAPTER

### 1 INTRODUCTION

1.1 Problem statement
1.2 Objectives of the study
   1.2.1 Main objective
   1.2.2 Specific objectives

### 2 LITERATURE AND REVIEW

2.1 Mechanization of corn production
   2.1.1 Tillage practice
   2.1.2 Crop protection or maintenance
   2.1.3 Harvesting operation
2.2 Fundamentals of technical and agronomy for corn
   2.2.1. Effective factors for optimum or maximum yields
2.3 Soil physical properties
2.4 Influence of tillage methods on soil properties, crop yield and consumed energy
2.5 Energy inputs to corn production
2.6 Agronomy of corn or maize
   2.6.1 Corn highlights
2.7 Corn production
2.8 Energy on drawbar of tractor and engine fuel consumption

### 3 MATERIALS AND METHODS

3.1 Machineries
   3.1.1 Tillage methods
   3.1.2 Soil and sweet corn characteristics
   3.1.3 Description of the experimental site
   3.1.4 Experimental processes for soil analyses
3.2 Experimental design
   3.2.1 Experimental design for the plots (before tillage operation)
and soil depth

3.2.2 Experimental design for tillage method and soil sampling at two depths 51

3.2.3 Experimental design for tillage method and planting density 52

3.3 Soil physical properties 52
  3.3.1 Soil sampling 52
  3.3.2 Soil texture 54
  3.3.3 Measurement of soil bulk density 54
  3.3.4 Measurement of soil total porosity 55
  3.3.5 Measurement of soil moisture content 55
  3.3.6 Measurement of soil aggregate size distribution and/or mean weight diameter, dry basis 55
  3.3.7 Measurement of aggregate stability or mean weight diameter, wet basis 56
  3.3.8 Measurement of soil resistance to penetration 58
  3.3.9 Measurement of water infiltration 59

3.4 Farm operations and data collection for sweet corn 59
  3.4.1 Harvesting operation, methodology determination of yield 61

3.5 Estimation of draft and power requirements 62
  3.5.1 Draught force per 1 meter of working width for various tillage implements 63
  3.5.2 Fuel consumption per hour, per hectare 65

3.6 Statistical analysis of research project 66
  3.6.1 Statistical analysis before tillage operation 66
  3.6.2 Statistical analysis after tillage operation 66
  3.6.3 Statistical analysis for tillage method and sweet corn planting density 67

4 RESULTS AND DISCUSSION 68

4.1 Climate and soil conditions of experimental site 68

4.2 Soil physical properties before soil tillage operation at two depths 71

4.3 Tillage effects on soil physical properties 74

4.4 Tillage effects on crop traits in 2008 85

4.5 Tillage effects on crop yield in 2009 and its comparison with 2008 97

4.6 Tillage effects on crop yield in both 2008 and 2009 103

4.7 Estimation of energy, fuel consumption and field capacity as a result of different tillage methods 108
  4.7.1 Draught force for Moldboard plough and drawbar power 109
  4.7.2 Draught force for Disc plough and drawbar power 109
  4.7.3 Draught force for Disc Harrow and drawbar power 110
  4.7.4 Power for Rotary Cultivator 110

4.8 Field capacity of tillage implements 111
  4.8.1 Field capacity for Moldboard Plough 111
  4.8.2 Field capacity for Disc Plough 111
  4.8.3 Field capacity for Disc Harrow 112
  4.8.4 Field capacity for Rotary Cultivator 112

4.9 Fuel Consumption per hour and per hectare 112
4.9.1 Fuel Consumption for Moldboard Plough 112
4.9.2 Fuel Consumption for Disc Plough 113
4.9.3 Fuel Consumption for Disc Harrow 113
4.9.4 Fuel Consumption for Rotary Cultivator 114
4.10 Economical analysis 114

5 CONCLUSION 125

- RECOMMENDATIONS 132
- REFERENCES 134
- APPENDIX A1 (Figure soil physical characteristics measurements) 143
- APPENDIX A2 (Figures related to machineries and tillage practices) 147
- APPENDIX A3 (Figures related to various growth stages) 150
- APPENDIX A4 (Figures measurement of crop yield and its components) 153
- APPENDIX A5 (Figures layout of experimental design) 157
- BIODATA OF STUDENT 161