

**Organically-grown tomato (*Lycopersicon esculentum*  
Mill.): Plant infection by *Phytophthora infestans* and fruit  
quality**

**Dissertation  
To obtain PhD Degree  
in the Faculty of Agricultural Sciences,  
Georg-August-University Göttingen, Germany**

**Presented by  
Afrah Eltayeb Mohammed  
Born in Elginaid, Sudan**

**Göttingen, November 2009**

### **Bibliografische Information der Deutschen Bibliothek**

Die Deutsche Bibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über <http://dnb.ddb.de> abrufbar.

D7

Referee: Prof. Dr. Elke Pawelzik

Co-referee: Prof. Dr. Heiko Becker

Co-referee: Prof. Dr. Petr Karlovsky

Date of examination: 12<sup>th</sup> November 2009

**Eltayeb Mohammed, Afrah:**

Organically-grown tomato (*Lycopersicon esculentum* Mill.):

Plant infection by *Phytophthora infestans* and fruit quality

ISBN 978-3-941274-34-1

Alle Rechte vorbehalten

1. Auflage 2010

© Optimus Verlag, Göttingen

URL: [www.optimus-verlag.de](http://www.optimus-verlag.de)

Das Werk, einschließlich aller seiner Teile, ist urheberrechtlich geschützt. Jede Verwertung außerhalb der engen Grenzen des Urheberrechtsgesetzes in Deutschland ist ohne Zustimmung des Verlages unzulässig und strafbar. Dies gilt insbesondere für Vervielfältigungen, Übersetzungen, Mikroverfilmungen und die Einspeicherung und Verarbeitung in elektronischen Systemen.

# Acknowledgements

First of all I owe great debt to Allah, the almighty God for keeping me healthy and able to do this work. It gives me great pleasure to express my deep thanks, gratitude and appreciation to my supervisor Prof. Dr. Elke Pawelzik. At the beginning I must thank her for giving me the opportunity to work at her group on this nice topic. I would like to express how grateful I am for her fruitful, excellent and keen guiding throughout the entire period of this work. Her limitless support, perfectionism, critical advices and sensible suggestions are highly appreciated. I must also direct my thank to Prof. Heiko Becker and Prof. Dr. Petr Karlovsky for agreeing to be the examiners for my PhD examination.

I have a sense of gratitude to PD Dr. Anna Keutgen for her great guidance and support to me through the provoking, frequent discussions, critical remarks, advices and suggestions. I must also thank Dr. Inga Smit for her various helps. Thank must also go to Dr. Bernd Horneburg for offering me different helps.

The cooperation that dominated among my colleagues in our working group has created a nice and motivating working atmosphere for me throughout the entire course of my study. With this feeling, I would like to thank all my colleagues in our working group. My experimental work could not have been accomplished without the cooperation and support I received from the technical staff in our working group. I would like to thank Gunda Jansen and Bettina Egger for their excellent technical assistance they offered me during the experimental period.

A warm vote of thanks must be extended to my family for her numerous helps; great support and encouragement all through the entire period of this study, special thank has to go to my friends and brothers Mohammed and Ammar Eltayeb for their kind feeling, help and concern during my study. Very special appreciation and gratitude must go to my small family here in Göttingen, Germany: my Husband (Mudawi), daughter (Hiba) and son (Mohammed). I would really like to thank Dr. Mudawi for his ever-continuous encouragement, patience, hearty prayers and unlimited moral support. Moreover, I acknowledge him not only for his critical amendments regarding the language, but also for the nice scientific discussions, from which I aquired good knowledge. Hiba and Mohammed are also greatly acknowledged for not only did they add a special piece of flavour to my stay in Germany, but also for keeping me inspired, optimistic and always motivated.

I do like here to send my special thank and appreciation to my sincere Sudanese friend Jalaa Elbashir for her continous helps during the critical periods in Göttingen. My friend and room mate Hanadi Eljabi, from Syria for her prayers and continous encouragement and helps. I will never forget their gentle support to me. To them and their families I send a lot of thank. Also, I wish to express my appreciation to my friends and colleagues Lele Win (Maynmar) for her kind and continous supports and helps. Suliman Hamad, Amro Babiker and their families are greatly acknowledged for their gentle support and encouragement. To Nuha Alali (Syria) I send a lot of thank. Much thank must go to Mutaz Magid for his generous help.

My thank is also extended to all Sudanese group, colleagues and friends not only in Göttingen, but in other cities in Germany, too. Also I will not to forget to send my thank to my colleagues from Sudan

who finished their PhD study, Dr. Kamal, Nasreen, Mai, Mahasin, Arafat and others who left already. It was really a nice and useful experience to be with this group. My thank is also extended to the Sudanese group who participated in my PhD graduation. My thank will not be complete without gratefully conveying my in-expressible thank to the Gottlieb Daimler- und Karl Benz - Stiftung for the generous financial support by providing the grant for me to persue my PhD in Germany. I would also like to thank this foundation for the nice annual workshops and meetings in Berlin and Lichtenfels.

Last, but not least, I would like to show my sincere gratitude to all my teachers and other people who helped me in a way or another throughout my educational life. To all of them, I dedicate this work with all the gratefulness, respect and appreciation.

# Tables of contents

<b>1. General introduction .....</b>	<b>1</b>
1.1 Tomato fruit production in organic agriculture .....	1
1.2 Tomato fruit quality .....	4
1.3 Effect of infection by <i>P. infestans</i> on tomato fruit quality .....	8
1.4 Research hypothesis .....	9
1.5 References .....	10
<b>2. Organically-grown tomato (<i>Lycopersicon esculentum</i> Mill.): Plant infection by <i>Phytophthora infestans</i> and fruit antioxidant contents.....</b>	<b>17</b>
2.1 Abstract .....	17
2.2 Introduction .....	18
2.3 Materials and methods.....	20
2.3.1 Experimental layout.....	20
2.3.2 Cultivation procedure .....	21
2.3.3 Evaluation of the leaf and fruit infection by <i>P. infestans</i> ....	24
2.3.4 Sample collection and quality measurements.....	24
2.3.5 Statistical analysis .....	27
2.4. Results and discussion.....	28
2.4.1 Effect of cultivar and location on the infestation by <i>P. infestans</i> .....	28
2.4.2 Different infection levels by <i>P. Infestans</i> and fruit antioxidants.....	33
2.4.2.1 Lycopene .....	33
2.4.2.2 Total phenolic compounds.....	34
2.4.2.3 Ascorbic acid.....	36
2.4.2.4 Antioxidant capacity.....	37
2.4.3 Effect of different years on the infection by <i>P. infestans</i> and fruit antioxidants .....	40

2.5	Conclusion.....	44
2.6	References .....	46
<b>3.</b>	<b>Organically-grown tomato (<i>Lycopersicon esculentum</i> Mill.): Plant infection by <i>Phytophthora infestans</i> and fruit mineral nutrients .....</b>	<b>53</b>
3.1	Abstract .....	53
3.2	Introduction .....	53
3.3	Materials and methods.....	56
3.3.1	Mineral nutrients determination .....	57
3.3.2	Statistical analysis .....	58
3.4	Results .....	58
3.4.1	Nutritional status of tomato and infection by <i>P. infestans</i> ...	63
3.5	Discussion .....	69
3.5.1	Nutritional status of tomato and infection by <i>P. infestans</i> ...	71
3.6	Conclusion.....	75
3.7	References .....	77
<b>4.</b>	<b>Organically-cultivated tomato (<i>Lycopersicon esculentum</i> Mill.): Plant infection by <i>Phytophthora infestans</i> and organic fruit compounds .....</b>	<b>84</b>
4.1	Abstract .....	84
4.2	Introduction .....	84
4.3	Materials and methods.....	86
4.3.1	Organic compounds measurements .....	87
4.3.2	Statistical analysis .....	89
4.4	Results .....	89
4.4.1	Quality parameters of different tomato cultivars as affected by environmental conditions .....	89
4.4.2	Relationship between infection by <i>P. Infestans</i> and fruit quality .....	97
4.5	Discussion .....	102

4.5.1 Quality parameters of different tomato cultivars as affected by environmental conditions .....	102
4.5.2 Relationship between fruit infection by <i>P. Infestans</i> and fruit quality .....	106
4.6 Conclusion.....	107
4.7 References .....	108
<b>5. Concluding summary .....</b>	<b>114</b>
<b>6. Appendices .....</b>	<b>117</b>
<b>7. Curriculum Vitae.....</b>	<b>141</b>



## List of tables

<b>Table 1.1</b> USDA National Nutrient Database for Standard Reference, 2008).....	7
<b>Table 2.1</b> Source, fruit colour and fruit weight of different tomato cultivars and breeding lines grown at Ellingerode and Schönhagen in 2004/2005.....	22
<b>Table 2.2</b> Geographical information about the locations, pre-crops, fertilization and planting dates in the locations in 2004 and 2005. ....	23
<b>Table 2.3</b> Evaluation key for the infestation of tomato leaves and the fruits by <i>P. infestans</i> .....	25
<b>Table 2.4</b> Fruit infection by <i>P. infestans</i> (AUDPC) of tomato cultivars in three different groups of infection levels at Ellingerode and Schönhagen in 2005.....	30
<b>Table 2.5</b> ANOVA for the effect of cultivar and location during 2005 at Ellingerode and Schönhagen for 28 tomato cultivars.....	41
<b>Table 2.6</b> ANOVA for the effect of cultivar and growing years, 2004 and 2005 at Ellingerode for 12 tomato cultivars. ....	42
<b>Table 2.7</b> Comparison of infection by <i>P. infestans</i> (AUDPC), yield (kg), antioxidant components (g kg <sup>-1</sup> FW) and antioxidant capacity (mmole Fe <sup>2+</sup> kg <sup>-1</sup> FW) for 12 tomato cultivars grown in 2004 and 2005 at Ellingerode. ....	44
<b>Table 3.1</b> ANOVA interaction for cultivar and location effects on the nutritional status of 28 tomato cultivars grown at Ellingerode and Schönhagen in 2005. ....	60
<b>Table 3.2</b> Comparative mean values of the investigated mineral nutrients. Data are expressed as mg kg <sup>-1</sup> FW for 12 tomato cultivars grown at Ellingerode for 2004 and 2005.....	63
<b>Table 3.3</b> ANOVA interaction for cultivar and year effects on the nutritional status and infection by <i>P. infestans</i> for 12 tomato cultivars grown at Ellingerode in 2004 and 2005.....	65

<b>Table 3.4</b> Pearson correlation coefficients between mineral nutrients of tomato fruits harvested in 2005 at Ellingerode .....	68
<b>Table 3.5</b> Pearson correlation coefficients between mineral nutrients of tomato fruits harvested in 2005 at Schönhagen.....	69
<b>Table 3.6</b> Minerals concentration ( $\text{mg kg}^{-1}$ FW) in different tomato cultivars irrespective to locations .....	74
<b>Table 4.1</b> Growing period and some quality parameters for tomato cultivars grown at Ellingerode and Schönhagen in 2005. ....	90
<b>Table 4.2</b> ANOVA interaction for cultivar and location effect on the tomato quality for 28 tomato cultivars grown at Ellingerode and Schönhagen. ....	99
<b>Table 4.3</b> ANOVA interaction for cultivar and year effect on some quality parameters for 12 tomato cultivars grown at Ellingerode in 2004 and 2005. ....	100