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

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CO_2	Carbon dioxide
BT	Baumtomate,
C	Carbon
Ca	Calcium
CE	Celsior
CG	Cerise gelb
CM	Celsior x Matina
CP	Cuban Pink
CR	Cerise rot
Cv	Cultivar
DW	Dry weight
FAO	Food and Agriculture Organization
Fe	Iron
FF	Ferline F1
FRAP	Ferric reducing ability of plasma
FW	Fresh weight
GAE	Gallic acid equivalent
GK	Goldene Königin
GM	Golden Currant x Matina
HF	Harzfeuer F1
HPLC	High pressure liquid chromatography
HT	Hybrid-2 Tarasenko
K	Potassium
L6	LYC 2466
L9	LYC 2469
LM	Lämpchen
MA	Matina
Mg	Magnesium
mmole	Ml mole
Mn	Manganese
N	Nitrogen
Na	Sodium
OR	Ostravske Rane
P	Phosphorus
P. infestans	*Phytophthora infestans*

PF	Phantasia F1
PH	Philovita F1
PO	Paprikaförmige
PU	Pfirsichhäutige
RG	Resi Gold
ROS	Reactive oxygen species
RR	Rosa Roma
SH	Schlesische Himbeer
SO	S 030a
USDA	United States Department of Agricultural Database
VF	Vitella F1
Z1	Z 21
Z2	Zuchtstamm22
Z4	Zuchtstamm 4
Zn	Zinc

1. General introduction

1.1. Tomato fruit production in organic agriculture

Tomato is one of the most widely grown vegetables in the world with a cultivation area of about 4.6 million ha year^{-1}. In 2007, tomato was ranked as the second most cultivated vegetable after potato with an annual production of about 130 million tons worldwide. At that time, the European Union was the second largest producer with 15.4% of fresh harvested tomatoes, after China. Tomato fruits are consumed all over the world with a consumption rate of 102.8 million tons year^{-1} (FAOSTAT 2009). Tomato fruit production has been mainly dependent on fungicides usage, but growing concerns about food safety and environmental pollution have increased the demand of organic products all over the world. Organic cultivation of tomato is one of the factors that are becoming major decision-making in tomato preferences for many consumers (Jones 2008).

Organic agriculture has substantial expansion in many countries over the last years reflecting the increased concern over environmental issues in conventional agriculture. Generally, more than 30.4 million hectares were managed organically by more than 7×10^5 farms worldwide from which organic vegetables cover about 0.18 million hectares. Only limited data are available about the organic tomato cultivation area worldwide, but in the USA and Saudi Arabia it was amounted to 2.7 and 100 hectares, respectively, of organically cultivated tomato (IFOAM 2008). However, fungal infection of the tomato plant in the field is one of the most important problems in organic cultivation (Punja 2004).

One of the most serious fungal diseases in organic tomato cultivation is the late blight caused by the soil-borne pathogen, *Phytophthora infestans.* This disease can spread rapidly during cool, rainy weather, killing plants within a few days and causing total crop loss (Wisler and Duffus 2000). *P. infestans* belongs to the group of Oomycetes, which are members of the kingdom Chromista and the order Peronosporales. *P. infestans* is worldwide distributed, but most severe epidemics occur in areas with frequent cool moist weather (Nelson 2008). *Phytophthora* has a devastating potential because it is multi-cyclic and can produce infectious inoculumcontinuously after the initial infection as long as the conditions remain favourable (O´Gara 2001).

Figure 1.1 Infection in tomato leaves and fruits by *P. infestans*

http://www.gardenersworld.com/how-to/problem-solving/tomato-blight/main.jpg

In the presence of moisture and low temperatures, zoospores are formed and released from sporangia. These zoospores swim in water and can migrate over the wet leaf surface. Coming in contact with the host tissue they encyst and germinate (Kamoun *et al.* 1998). If the temperature is over 15°C, however, the sporangia will most likely germinate directly into a germ tube and penetrate the leaf tissues. Penetration can also be indirectly through the open stomata (Vleeshouwers *et al.* 2000). Symptoms on plants include black lesions on the stems and leaves and rapid wilting (Kamoun *et al.* 1999).

Attempts at limiting losses in agriculture due to diseases are commonly based on extensive use of fungicides. The only effective fungicides against *P. infestans* in organic farms are copper-based with a maximum permitted application in Germany of 3 kg pure copper per hectare and season (Tamm *et al*. 2004). Copper is a heavy metal that remains in the environment (Brümmer *et al.* 1986). Therefore, copper fungicides are totally prohibited in the Netherlands and Scandinavia, the European Union is aiming to prohibit copper in the foreseeable future and hence there is a serious need for alternative strategies for disease control (Tamm *et al*. 2004).

Application of compost as organic fertilizer has been used successfully to suppress soil-borne pathogens such as *Fusarium, Phytophthora, Pythium, Rhizoctonia and Verticillium* (Termorshuizen *et al.* 2006). It has been found that by limiting or prohibiting the use of synthetic pesticides, under organic production methods the plants develop better abilities toward the synthesis of their own physiological defense mechanisms (Winter 2006).

Tomato is characterized by a great diversification due to the greatly varied uses and its adaptation to different cropping systems. As a result, hundreds of tomato cultivars are now available, which differ also in their resistance to pathogen infection. Furthermore, these differences might be reasons for many breeding and screening programmes in order to obtain tomato cultivars with high levels of resistance to the major fungal diseases. The great success achieved in the development of cultivars resistant to fungi was obtained due to the availability of dominant genes of resistance (Prohens and Nuez 2008).

Seen from a historical perspective, breeding goals in tomato have gone through four phases: breeding for yield in the 1970s, for shelf-life in the 1980s, for taste in the 1990s and for nutritional quality currently. To be successful, growers must produce a high yield of high-quality fruit, while holding production costs as low as possible. Therefore, many of the breeding goals focus on characteristics that reduce production costs or ensure reliable production of high yields with high-quality fruits (Bai and Lindhout 2007)

1.2. Tomato fruit quality

Tomato fruit quality is characterized by its organoleptic quality, involving taste, color, flavour and texture. These parameters make a product satisfactory for the consumers. The nutritional quality is also characterized by a number of parameters responsible for properties related to human health (Anza *et al.* 2006). Flavour and taste are mainly determined by sugars and organic acids contents. The tomato fruit composed mostly of water with about 5–7% of solids. Half of these solids are composed of sugars and one eighth of acids which are important fractions of tomato flavour. The higher the solids content, the higher the fruit flavour (Jones 2008). Sugars constitute about 50% of fruit dry matter, which are about 22% glucose, 25% fructose and

1% sucrose. Organic acids comprise about 15% of the dry matter of fresh fruits (Jones 2008).

Regarding nutritional quality parameters, minerals constitute about 8% of the dry matter content of tomato. Potassium and phosphorus are the two major nutrients (Yilmaz 2001). Tomato is also an excellent source of many secondary metabolites important for human health such as folate, ascorbic acid, flavonoids, chlorophyll, β-carotene and lycopene (Wilcox *et al*. 2003).

Generally, tomato fruits contain nutrients that are characterized as antioxidant components such as:

- The membrane-associated antioxidant lycopene, which is responsible for the reddening of the fruits. Due to the differentiation of the chloroplasts and chromoplasts, lycopene is very important with regard to the final nutritional and marketable quality of tomato (Dumas *et al.* 2003). According to Dumas *et al.* (2003), the skin of tomato contains five times more lycopene (540 mg kg^{-1} FW) than the pulp (110 mg kg^{-1} FW).

- The water soluble antioxidant ascorbic acid, which is a six-carbon lactone synthesised in a plant from the sugars formed during photosynthesis (Walingo 2005). All higher plants contain high levels of ascorbic acid distributed in many different cell compartments, such as the cytosol, mitochondria, chloroplast, and apoplast. Plants are the main nutritional source of ascorbic acid in human nutrition (Siendones 1999). In both plant and animal metabolism, the biological functions of ascorbic acid are linked to the antioxidant properties of this molecule (Davey *et al.* 2000). The normal range of ascorbic acid in tomato is between 84 and 590 mg kg^{-1} FW (Dumas *et al.* 2003).