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Correlation between cell size and blackspot of potato tuber parenchyma tissue after storage

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ABSTRACT

Mechanical injuries are the main cause of damage and loss of quality of plant raw materials. Potatoes are susceptible to external and internal pressures, which cause bruising and fracture in soft tissues. The paper shows research concerning the relationship between geometrical parameters of the microstructure of potato tuber tissue and susceptibility of potatoes to blackspot damage after six months of storage. Twenty eight potato varieties from 2011 and 2012 crops in Poland were used in the experiment. The tubers had a similar size and shape. A TRSLM confocal microscope was used to study the microstructure of soft tissue in potato tubers and microscope images of the perimedullary zone of the tissue were analyzed.

The study shows that there is a correlation between the size of perimedullary tissue cells in potato tubers and blackspot damage. Potato tubers with smaller cells of the perimedullary zone show higher susceptibility to blackspot damage, described by the blackspot index BIP, in comparison with potatoes with larger cells which were stored for six months.

1. Introduction

Besides wheat, corn, and rice, potatoes are the world's major cultivated plant with a multipurpose use (Burton, 1989; Olsen, 2014; Devaux et al., 2014). Potato tubers are used in direct consumption, food industry, and for production of fodder, starch, ethanol, and boxes (Mościcki et al., 2006; Mullins et al., 2006; Andre et al., 2014; Wuyts, 2014).

Potatoes are subject to the action of external forces during production, harvesting, and storage. These external forces can cause irreparable damage, which is visible as bruising, discoloration, and cracking (Marks and Wiwatowski, 2012; Peters, 1996; Malaga-Toboła, 2007; Bojanowski et al., 2013; Baritelle and Hyde, 2003). This leads to deterioration of raw material and decreased quality of the end-products (Opara and Pathare, 2014; Graveland, 2014) and causes economic losses (McGarry et al., 1996; Käppeler, 2004). One of the problems is blackspot damage, which can reduce the quality of potato tubers and is difficult to detect in the intact tuber.

The blackspot is an aftermath of cell structure damage as a result of mechanical injury, physiological stress, or development of diseases (Storey, 2007; Singh et al., 2014). Melanin (black in color) is produced when phenolics come into contact with polyphenol oxidase as a consequence of cell damage induced bv mechanical injuries (Reeve, 1968; Stevens et al., 1998). Localized blackened tissue that is a result of mechanical injury is called blackspot damage (Zgórska and Frydecka-Mazurczyk, 2000). Blackspot is a kind of damage that is seldom visible after harvest but appears during storage (Blahovec 2006). Given the available state of knowledge and technique, it is currently impossible to determine the susceptibility to this type of damage immediately after harvesting (Blahovec, 2006); therefore, the susceptibility index obtained for ca. 6-month storage of potato tubers in the preceding year is used.

The microstructure is one of the most important features of plant tissues determining their quality and usability, especially those connected with mechanical features (Aguilera, 2005; Winisdorffer et al., 2015; Kaack et al., 2002). The microstructure of plant tissues, including potato tubers, is influenced by the variety, type of tissue, fertilization, environment, time of harvest, and storage conditions. It is changed by mechanical and thermal effects. If the mechanical stress acting on the plant tissue by the long time or increased the higher number of damaged cell walls and reduction in the cell size are observed. Whereas the reduction in the temperature of the plant tissue leads to collapse of the cell walls and tearing of the tissue. As a result of these effect, the cell separation with the presence of larger intercellular spaces is observed (Sun and Li, 2003; Konstankiewicz et al., 2002; Gancarz and Konstankiewicz, 2007a; Zdunek et al., 2008; Chassagne-Berces et al., 2009). Geometrical features of plant tissues determine tissue mechanical characteristics (Devaux et al., 2008). Knowledge about

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the relationship between geometrical features of plant tissues and susceptibility to blackspot damage is essential for better understanding how blackspot arises.

When blackspot develops, only the cell membrane is damaged but the cell wall is intact (Edgell et al., 1998; Partington et al., 1999; Reeve 1968). There are many factors influencing blackspot damage. The size and shape of the tuber are important morphological traits for development of blackspot. Larger tubers are more susceptible to blackspot (McGarry et al., 1996; Baritelle and Hyde, 1999,2003). Mohsenin (1986) noted that the radius of tuber curvature influences the type of damage. The larger the radius of tuber curvature, the higher susceptibility to internal damage. Baritelle and Hyde (1999) reported that the stem end of tubers is more susceptible to blackspot than their perimedullary zone and bud end. Smittle et al. (1974) studied the relationship between cells damaged at 7–10 °C and turgor. Less irrigated tubers are more susceptible to blackspot. Investigations of the relationship between the size of the cell and susceptibility to blackspot conducted so far are not sufficient. Hudson, (1975) showed that cell size (r^2 = 0.485) and intercellular spaces (r^2 = 0.474) have an influence on the depth of occurrence of blackspot in tubers. The bigger the cells are, the deeper the blackspot is. Umærus et al. (1976) and Aeppli and Keller (1979) in the research of the relationship between the size of the cell and susceptibility to blackspot did not show a correlation between the cell size and blackspot susceptibility. There are no studies focused on verification of these relationships that would be carried out using more modern devices with better accuracy, facilitating better subsequent analysis.

In the case of tissue damage arising as a result of an externalforce, it is predictable that the geometrical features of tissue connected with mechanical endurance will influence occurrence of the damage. The aim of the research is to determine the relationship between the size of the perimedullary zone of potato tuber cells and susceptibility to blackspot damage.

2. Materials and methods

2.1. Materials

The studies were carried out on twenty eight varieties of potatoes (*Solanum tuberosum* L.) cultivated in 2011 and 2012: Asterix, Andromeda, Bartek, Czapla, Denar, Fresco, Irga, Irys, Pasat, Roxana, Syrena, Tajfun, Victoria, Vineta in 2011 and the same varieties in 2012. For both years the tubers were stored for six months in constant conditions of humidity (95%) and temperature (4 °C). All varieties were obtained from one producer in Nowosiółki (Poland). All varieties were cultivated on black earth. A green fertilizer (white mustard 3 kg m^{-2}) and a mineral fertilizer N:P:K in an amount of 9:8:12 ($\times 10^{-3}$ kg m^{-2}) were used. Tubers were collected in their full ripeness phase. The varieties had different degrees of susceptibility to blackspot damage, according to the information provided by the PBAI (2010).

2.2. Methods

2.2.1. Tuber selection

Ten similar-size tubers of each variety were used in the studies. Tuber selection was made using image analysis, which was described by Gancarz and Konstankiewicz (2007b). The tuber size and shape was defined on the basis of the surface and elongation at a flat tuber image (Gancarz and Konstankiewicz, 2007b). The tubers used in the research had a surface area in the range from 12.56 cm^2 to 28.26 cm^2 and elongation from 0 to 0.2. This corresponds to a tuber fraction of 4–6 cm, which is the most useful in industry.

2.2.2. Simulation of exterior interaction–CHMI technique

Each tuber subjected to mechanical using the CHMI technique—(Constant Height Multiple Impacts), (Bajema and Hyde, 1998). The technique relies on throwing the same part of a tuber on hard

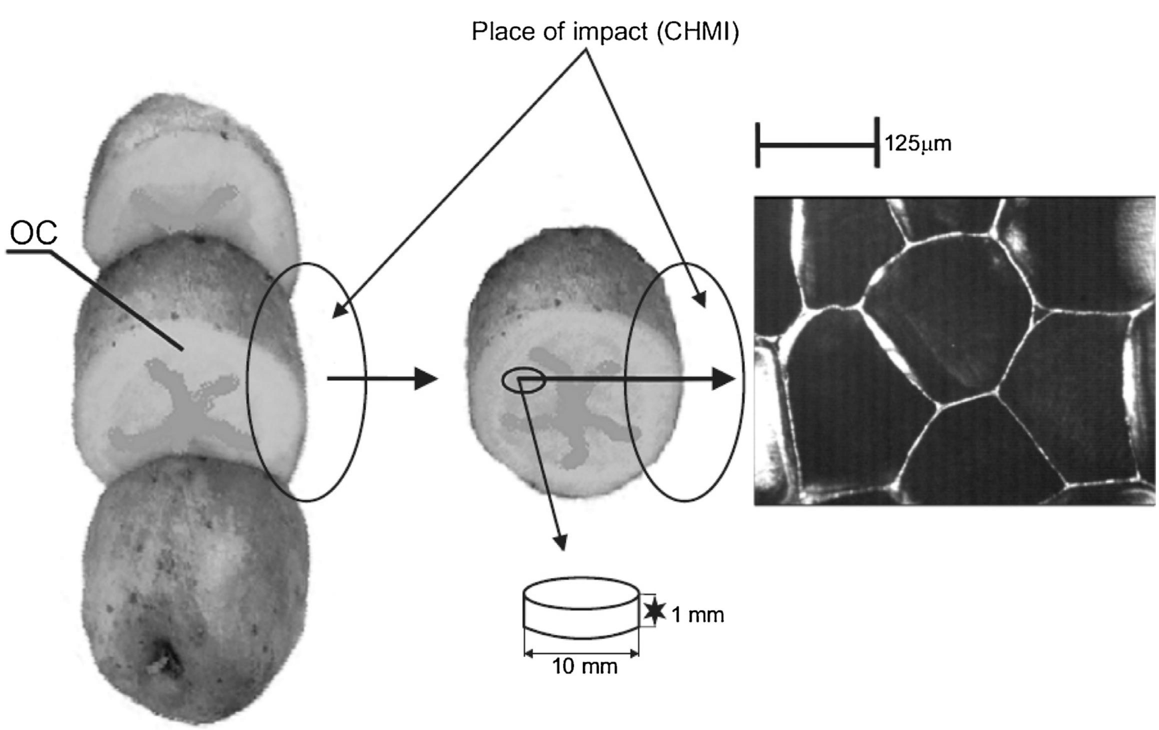

Fig. 1. Sampling scheme, perimedullary zone—(OC).