ISSN 1392-3196
Žemdirbystė=Agriculture, vol. 98, No. 1 (2011), p. 3–10
UDK 633.11:581.144.4:632.481:632.2

A review of tan spot research in the Baltic countries: occurrence, biology and possibilities of control

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Abstract

Tan spot (caused by *Pyrenophora tritici-repentis*, anamorph *Drechslera tritici-repentis*) is one of the most important wheat leaf diseases all over the world, especially in the regions of intensive wheat growing. Tan spot was noticed and identified in Latvia and Lithuania in the first half of the 1990s when an increase in wheat proportion in a crop rotation caused rapid spread of the disease. In some cases, the incidence of tan spot approached 100% and severity reached 70% in Lithuania and Latvia. The paper gives a review of the literature by different authors, but mainly focuses on the research carried out in Latvia and Lithuania.

Key words: *Pyrenophora tritici-repentis*, harmfulness, severity, symptoms, life cycle.

Introduction

Tan spot is one of the most important and harmful diseases of wheat in Latvia and Lithuania. There are a lot of articles covering different aspects of the morphology of the pathogen as well as biology of the disease in the world literature. Some important papers have been published regarding the peculiarities of tan spot development in Latvia and Lithuania. The present review article describes symptoms of the disease, its morphological traits, and characteristics of the life cycle under the conditions of the Baltic region.

Occurrence and harmfulness of tan spot in the world and in the Baltic region

Tan spot is one of the most important wheat leaf diseases all over the world, especially in the regions of intensive wheat growing. The disease was first identified in the United States in the 1940s, and since then its incidence and severity have steadily increased (Wolf et al., 1998; Ciuffetti, Tuori, 1999).

In Latvia and Lithuania, tan spot was noticed and identified in the first half of the 1990s. The spread of the disease rapidly increased with the increase in wheat percentage in a crop rotation. The process of disease incidence and severity increase is also linked with the change in the varietal composition and the expansion of the area under minimum tillage, which allows the inoculum to build up on wheat stubble over time (Bankina, 2000). In recent years tan spot has become a potentially destructive disease of wheat (Ronis et al., 2009).

Observation results in Lithuania have shown that severity of the disease fluctuates depending on the year and variety reaching nearly 70% (Ronis, Semaskiene, 2006). The impact of tan spot in the complex of necrotrophic wheat leaf diseases has been estimated in Lithuania. The proportion of the area under diseases progress curve (AUDPC) of tan spot fluctuates from 66.7% to 100% in the total leaf spot disease pressure (Ronis, 2008).

In Latvia, tan spot is one of the most widespread and harmful leaf diseases of wheat at present. A large number of observations were made during 1999–2004. The occurrence of tan spot was very frequent during this period reaching on average 96%, but its severity fluctuated between varieties and fields (Bankina, 2005; Bankina, Priekule, 2005).

In Estonia, tan spot has not been noted as an important wheat disease. Septoria leaf and glume blotches and powdery mildew have caused the most important economic losses in wheat production in this country (Koppel et al., 2003; Sooväli et al., 2006).

Yield losses caused by tan spot may reach 30–50% in years favourable for the disease development (Shabeer, Bockus, 1988). Yield losses depend on tan spot epidemiology in a definite vegetation period. Early disease development causes 13%, late disease development 35%, and throughout the season 48% yield reduction (Rees, Platz, 1983).

In Lithuania, harmfulness of tan spot has been studied very thoroughly. With the increase in severity of leaf spot diseases (including tan spot), the number of productive tillers per square meter and the number of grain per ear tend to decline. The closest negative correlation has been observed between disease severity and thousand grain weight (TGW) in the years favourable for disease development. Up to 69% reduction in TGW was recorded with the level of disease severity ranging from medium to high (Ronis, 2008, Ronis et al., 2009).

Symptoms and the causal agent of tan spot

First symptoms are distinct black spots (Ø 1–2 μm) with a white area shaped at the centre as a result of collapse of 1–3 epidermal cells. Chlorotic or necrotic areas develop around the spots. The type, shape and size of spots depend on environmental factors and wheat varieties reaction against infection and the reaction against pathogen of the wheat variety. The lesions coalesce and produce large areas of dead tissue during the progress of the disease. Severely diseased leaves eventually wilt and die prematurely (Wolf et al., 1998).

P. tritici-repentis can also infect wheat grain during the grain filling period. This disorder is called red smudge, because of salmon-pink or red discoloration at the embryo end or elsewhere on the grain surface (Bergstrom, Schilder, 1998). Small, brown lesions up to 2 mm in length are observed on the coleoptile and occasionally on the first leaf if grains have been infected (Bergstrom, Schilder, 1998). *P. tritici-repentis* is also one of the pathogens associated with black point of wheat (Wolf et al., 1998). *P. tritici-repentis* on grains has been found in Lithuania.

For the first time the causal agent of tan spot was isolated from blue-grass (*Agropyron repens*) and described as *Pleospora trichostoma* in 1902, and afterwards designated as *Pleospora tritici-repentis* by Diedicke in 1902 (Wolf et al., 1998). Sexual stage has been named variously – *Pleospora tritici-repentis* Died., *Pleospora trichostoma* f. sp. *tritici-repentis* (Died.) Noack, *Pyrenophora tritici-repentis* (Died.) Drechs., *Pyrenophora tritici-vulgaris* Dickson. The conidial stage was initially known as *Helminthosporium graminearum* f. sp. *tritici-repentis* (Rab. ex Schlecht.) Died., *Helminthosporium tritici-repentis* (Died.) Died., *Helminthosporium tritici-vulgaris* Nisikado, *Drechslera tritici-vulgaris* (Nisikado) Ito, and *Drechslera tritici-repentis* (Died.) Shoem. *Pyrenophora tritici-repentis* (Died.) Drechs. (teleomorph) and *Drechslera tritici-repentis* (Died.) Shoem. (anamorph) are accepted terms at present (Wolf et al., 1998).

Conidia of *Drechslera tritici-repentis* are dark, cylindrical, with 5–13 septa (mostly 4–7) (Fig. 1).

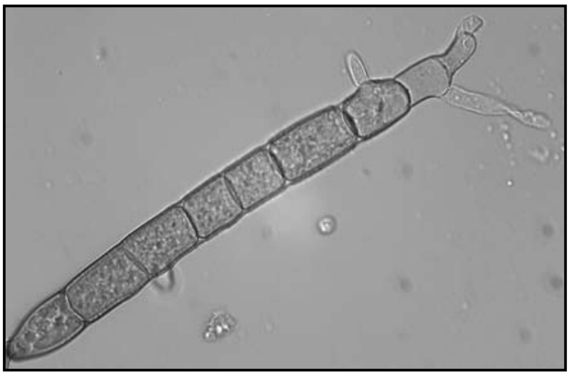

Figure 1. Conidia of *Drechslera tritici-repentis* (magnification 400 ×)

Teleomorph develops on the debris of wheat straws. Stromatic peritheciums (pseudotechia) of *Pyrenophora tritici-repentis* are black, partly erupted, with characteristic dark setae around ostioles (Fig. 2).

Figure 2. Pseudotechia of *Pyrenophora tritici-repentis* on the straw

Asci are clavate, normally each ascus contains eight ascospores. Ascospores are dark, three septa transversely; median cell may have longitudinal septation (Fig. 3). Paraphyses also are typical for pseudotechia of *P. tritici-repentis*. Pseudotechia with ascospores have been found in Latvia (Bankina, 2005). Morphological peculiarities of pseudotechia, asci and ascospores correspond to the description in the literature (Wehmeyer, 1954; Shoemaker, 1962; Wolf et al., 1998).

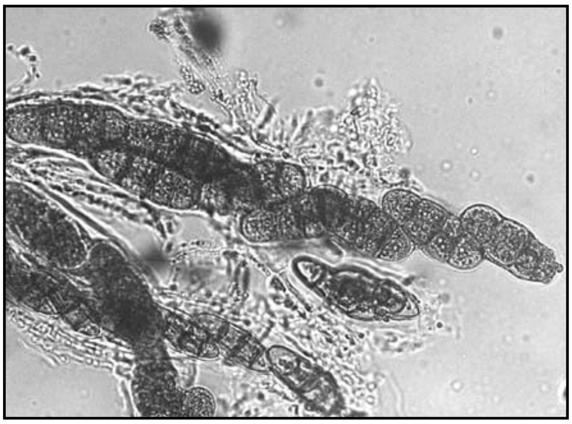

Figure 3. Asci of *Pyrenophora tritici-repentis* with ripe ascospores (magnification 400 ×)

Specialization of *Pyrenophora tritici-repentis* has been studied all over the world. Collateral hosts of the pathogen could play an important role as a source of primary inoculum between the growing seasons, and as a source of a fungal population genetically different than that prevalent on wheat (Wolf et al., 1998). More than 26 host plants have been identified (Krupinsky, 1982). Physiological specialization of *P. tritici-repentis* has been studied by symptoms on the leaves (development of chlorosis and necrosis on the leaves depending on the variety) (Lamari, Bernier, 1989; Lamari et al., 1991). There have been eight races of pathogen differentiated over the world (Strelkov, Lamari, 2003). The structure of pathogen populations (composition of races) has not been identified in the Baltic countries yet.

Research results of the pathogenity of *Pyrenophora tritici-repentis* show that the fungus produces several host-specific toxins influencing disease severity and symptom display in susceptible wheat varieties. Toxins are presently divided into two groups based on their ability to produce either tan necrosis or chlorosis symptom. Ptr ToxA (necrosis-inducing) and Ptr ToxB (chlorosis-inducing) have been determined as the main toxins (Wolf et al., 1998).

Life cycle and biology of tan spot

The primary disease infection on wheat is initiated by ascospores having developed in pseudotechia which in their turn had developed on infested wheat straw debris. Time of pseudotechia initiation, maturation, as well as ascospore differentiation varies from region to region. The release of ascospores starts in spring and can continue all the season. Liberation of ascospores is favoured by rainfall (can also be associated with high relative humidity) and temperature >10°C (Wolf, Hoffmann, 1994).

The secondary infection occurs when conidia develop on the necrotic leaf lesions (can also occur on plant debris). Best of all conidia are produced on leaves which are wet during darkness but dry during daylight (Francl, 1998). Germination of conidia is possible in large amplitude of temperature (10–28°C). The length of incubation period (from infection till symptoms) depends on resistance of variety and meteorological conditions, but continues approximately 5–6 days (Riaz et al., 1991).

Severity of tan spot fluctuates between varieties and years (0.5–70.0%) at the time of milk ripeness under conditions of Latvia. It is an important task to understand the reasons for such a wide difference in tan spot severity. A significant influence of year has been demonstrated by statistical methods of investigations. Difference between varieties is substantial (coefficient of variance – 27.6), but the influence of year is even more significant (coefficient of variance – 71.6) (Bankina, 2002). The role of a variety and different levels of varietal resistance have been confirmed in Lithuania too (Semaskiene, Ronis, 2004).

In Latvia, the time of the appearance of the first tan spot symptoms depends on meteorological conditions and varieties (Fig. 4). Tan spot was observed at the stage of stem elongation (DC 32–34) in 2003, but in 1999 – only after flowering (DC 65–69). Previously, first symptoms of the disease had been observed on early varieties. It is very difficult to explain so large differences, because relationships between the weather conditions and the time of first symptoms have not been established. For example, in 2003, although spring was cool and dry, tan spot appeared very early. The occurrence and amount of infection sources probably is the most important cause of the diverse starting time of the disease development (Bankina, 2002).

The time of the appearance of the first symptoms may not correlate with the following development of the disease. For example, in Fig. 4, in trial 5 (the year 2000), the first symptoms were observed in DC 55 and the following disease development was fast, which resulted in 5% severity already in DC 65. A completely different disease progress was observed in trial 12 (the year 2001), when the first symptoms were observed in DC 39–41, but 5% severity – only in DC 75.

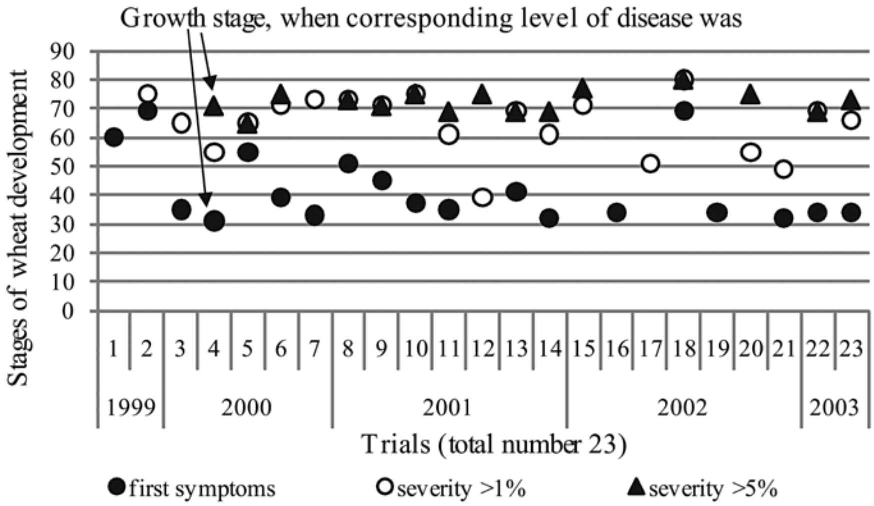

Figure 4. Time of different steps of disease development depending on year and sites in Latvia

Differences and peculiarities of the disease epidemic between varieties and years are reflected by the disease progress curves (DPC). DPCs represent the integration of all – host, pathogen, and environmental factors, allowing analyzing and understanding the development of the disease (Campbell, Madden, 1990).

DPCs were constructed assessing severity of tan spot over time in Latvia during 1999–2004. Increase in the disease severity was slow until the stage of heading (DC 50–59). Sharp increase in the disease was observed at the late stages of wheat development (Fig. 5). DPCs giving a possibility to evaluate the differences between AUDPC were used to compare the epidemics and quantitatively measure their intensity and development. The volume of AUDPC differed between varieties, years and sites of observation, but shapes of DPC were very similar (Fig. 5).

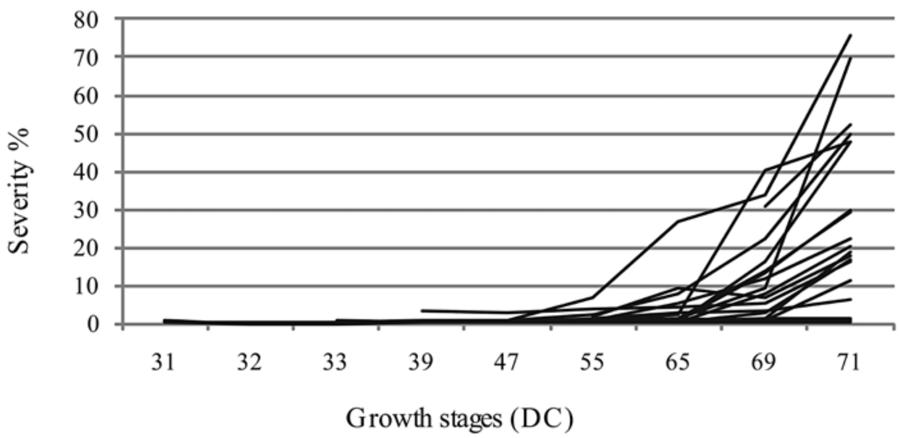

Figure 5. Dynamics of tan spot development disease progress curves depending on year (2000–2004), variety (‘Donskaja polukarlikovaja’, ‘Kontrast’, ‘Krista’, ‘Stava’, ‘Zentos’, and ‘Bussard’), and site of observation (Jelgava, Peterlauki, Stende, Priekuli, and Vilani) in Latvia

Collection of data from different trials allowed designing a model of tan spot development in Latvia’s conditions (Fig. 6). Sharp development of the disease was observed after heading and especially during flowering.

Wegulo et al. (2009) have reported that disease severity increases exponentially only after wheat flowering till milk ripeness. Similar results were obtained in Lithuania, where development of tan spot was investigated during three years with different meteorological conditions. Rapid increase of disease severity was observed only during flowering (2004 and 2005) and only during ripeness in 2003 (Ronis, Semaskiene, 2006).

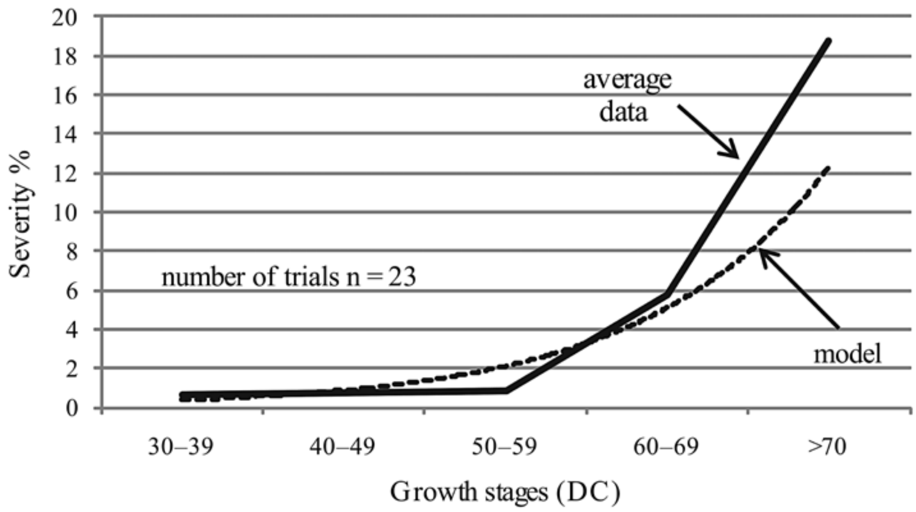

Figure 6. The typical curve of tan spot development during the vegetation season

These peculiarities may be explained by the rate of infection of tan spot. Rate of infection characterizes increasing of diseases' severity during one day (Campbell, Madden, 1990). In Latvia, in 1999–2004, the rate of infection was very slow (close to zero) until the milk ripeness stage, only in some cases it increased at the time of tillering, afterwards the rate of infection decreased (Bankina, 2002; Банкина, Ружа, 2004). The most intensive development of the disease was observed after flowering (Fig. 7). There are some reasons for such tendency: conditions for liberation, dispersal and germination of ascospores as the main agent of infection, development of conidia on the lower senescent leaves, and changes in wheat resistance were related to the crop age. Resistance against *P. tritici-repentis* decreases during dough stage (Hosford et al., 1990).

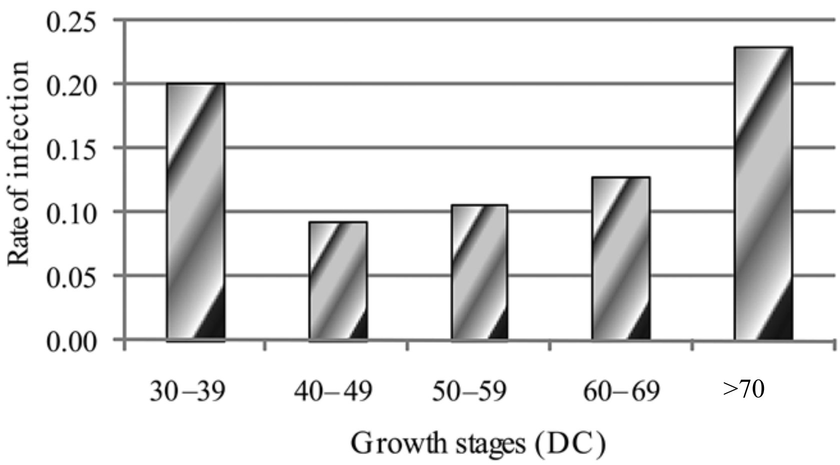

Figure 7. Average rates of tan spot infection in Latvia in 1999–2004 (Банкина, Ружа, 2004)

Development of the disease depends on the source of infection. The main source of infection is wheat straw debris (Wright, Sutton, 1990; Wolf et al., 1998; Semaskiene, Ronis, 2004). Pseudotechia develop on the stems after lasting saprophytic growing of mycelium which is about two months after harvesting under conditions of Latvia. Asci and ascospores do not differentiate during autumn. Differentiation of spores starts in spring (March–April), and ripe ascospores are observed during May. Ripening of ascospores occurs gradually. Dispersal of ascospores continues throughout the growing season period till late November. Conidia develop only on the senescent spots therefore ascospores are the main agent of infection. The relative contribution of ascospores and conidia to the primary inoculums' dosage needs further studies under conditions of the Baltic region. Further investigations into importance of relationships between different infection (ascospores/conidia), wheat development stages, and meteorological parameters are necessary.

Experimental evidence in Lithuania suggests that optimal temperature for the availability of ascospores at the time of stem elongation might lead to a severe epidemic of tan spot (Ronis, Semaskiene, 2006). The amount of rainfall has no significant effect on the disease development during this period, because soil moisture is the most important factor (Bockus, Shroyer, 1998). Rain plays a major role in the development of tan spot in the post-inoculation period, which is the time of heading or later under field conditions in the Baltic region (Ronis, Semaskiene, 2006).

Control of the disease

Agronomical practise is the most important factor which influences the incidence and severity of tan spot. Crop rotation and soil tillage significantly decrease development of tan spot. The use of no-till practice for wheat enlarges the amount of wheat straw on the soil surface and increases severity of tan spot (Carigano et al., 2008; Ronis et al., 2009). The level of tan spot in plots with reduced tillage is 4–10 times higher than in plots with full tillage (Jorgensen, Olsen, 2007).

Clear and significant differences in the level of attack among varieties have been estimated not only in Denmark (Jorgensen, Olsen, 2007), but also in Latvia and Lithuania, but more investigations are necessary to determine most resistant varieties, because only some varieties were observed. Therefore fungicide application is necessary, especially under conditions of intensive wheat growing and favourable weather conditions in Latvia and Lithuania (Priekule, Bankina, 2004; Gaurilcikiene, Ronis, 2006).

Research results in Denmark show that products containing strobilurins together with propiconazole gave the best control of tan spot. The efficacy reached 55–97% depending on the number of treatments and doses of fungicides (Jorgensen, Olsen, 2007).

Significant yield increases have been obtained by protecting wheat plants against leaf spot diseases using triazole fungicides in the trials in Lithuania. For most of the varieties, 1.0–5.0% severity of tan spot has been the threshold of significant yield losses (Ronis et al., 2009). Investigations into the application of fungicides for tan spot control in Latvia have demonstrated fluctuations in biological efficacy of around 70% depending on the variety, the year, and fungicide application schedule (Priekule, Bankina, 2004), in Estonia – reference Sooväli et al. (2006).

The obtained results are controversial, and the efficacy of fungicide application is similar in different schedules of treatment. Further investigations are necessary for better understanding of the relationships between severity of the disease, fungicide treatment, and yield losses.

Conclusion

Occurrence, incidence, severity and harmfulness of the tan spot have been investigated in Lithuania and Latvia. Morphological peculiarities and life cycle were clarified under the conditions of the Baltic region. The most crucial points of disease control are described, but further, more comprehensive investigations are necessary in this area. Identification of *Pyrenophora tritici-repentis* races and investigations of pathogen biological diversity are the most important tasks in the future.

Received 18 10 2010
Accepted 29 12 2010

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ISSN 1392-3196
Žemdirbystė=Agriculture, vol. 98, No. 1 (2011), p. 3–10
UDK 633.11:581.144.4:632.481:632.2

Kviečių dryžligės tyrimų Baltijos šalyse apžvalga: paplitimas, biologija ir kontrolės galimybės

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Santrauka

Dryžligė, sukelta *Pyrenophora tritici-repentis*, anamorfa *Drechslera tritici-repentis*, yra viena pagrindinių kviečių lapų ligų visame pasaulyje, ypač kviečių intensyvaus auginimo regionuose. Kviečių dryžligė Latvijoje ir Lietuvoje buvo pastebėta ir identifikuota praėjusio amžiaus pabaigoje, kai didėjanti kviečių dalis sėjomainoje lėmė greitą šios ligos paplitimą. Lietuvoje ir Latvijoje kai kuriais atvejais dryžligės paplitimas siekė 100 %, o ligos išsivystymas – 70 %. Straipsnyje pateikta įvairių autorių literatūros apžvalga, didžiausią dėmesį skiriant Latvijoje ir Lietuvoje atliktiems tyrimams.

Reikšminiai žodžiai: *Pyrenophora tritici-repentis*, žalingumas, išsivystymas, simptomai.