Advances in Engineering Research, volume 151
International Conference on Smart Solutions for Agriculture (Agro-SMART 2018)

Biodiversity of Plant Pathogens in the context of International Economic Issues

Case Study of Tilletia Controversa Kuehn

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***Abstract*—Globalization as a process of world economic, political and cultural integration requires strengthening of control over dangerous plant diseases, pests and weeds. This is evidenced by strengthening of phytosanitary requirements in some countries (the People's Republic of China imposed a ban on wheat supplies from the European part of the Russian Federation due to a quarantine object - dwarf smut Tilletia controversa Kuehn found in wheat; Jordan reduced the permissible Fusarium infection rate of wheat grain to 0,03%), and environmental disasters caused by invasive species**

Keywords— winter wheat, dwarf smut, harmfulness, grain imports, phytosanitary requirements

I. INTRODUCTION

In 2012, the Russian Federation joined the World Trade Organization. One of the entrance conditions is phytosanitary measures and environmental protection ("green basket") which should be prioritized. However, monocultures, short and resource-saving surface tillage crop rotations, low saturation of crop areas with resistant varieties caused serious phytosanitary problems. Currently, there is a variety of stem and foot rot, leaf and head diseases. In a number of regions, phytosanitary destabilization due to sustained disturbance of biocenotic equilibrium in agrocenoses has become of a deep protracted character with large economic losses and expansion of dominant malicious objects [1].

The range of dangerous and harmful diseases of wheat - dwarf smut caused by Tilletia controversa Kuehn is being expanded. Due to its high harmfulness, the causative agent of this disease is an important international quarantine object in many countries [2–4]; it is included in the A2 list of quarantine organisms of the European and Mediterranean Plant Protection Organization (EPPO). Tilletia controversa Kuehn is a quarantine object in the Inter-African Phytosanitary Council (IAPSC) and the North American Plant Protection Organization (NAPPO) [5].

In 1997, China imposed a ban on importation of Russian wheat infected with dwarf smut (Tilletia controversa Kuehn).

II. EXPANSION AND HARMFULNESS OF THE WHEAT DWARF SMUT

Currently, the disease is registered in many countries in the area between 41 и 530 north latitude in Europe, for example, in the Czech Republic [6], and between 37 and 380 north latitude in North America. Field researches conducted by B. Goates, G.L. Peterson, R.L. Bowden, L.D. Maddux [7] in the state of Kansas whose soil and climatic conditions are similar to the ones in northern China where wheat is cultivated confirmed the possibility of dwarf smut expansion. Moreover, Wen-mmg Jia et al. [8] developed a dwarf swut expansion risk assessment map based on five-year data from five hundred Chinese meteorological stations, information on pathogen biology and ecology and disease epiphytotiology, using GIS technology. The map formed a basis for quarantine regulatory acts.

It is emphasized that the disease is typical of elevated, foothill areas of wheat cultivation. In particular, in Stavropol Krai, the disease affects winter wheat crops located on Stavropol Upland and spurs of the Greater Caucasus Mountains (Aleksandrovsky, Kochubeyevsky, Mineralovodsky, Predgorny, Shpakovsky Districts) at a height of 150 m above the sea level. Most areas of the range belong to the moderate moisture zone (450-550 mm per year). Keener T.K., Stougard R.N., Mathre D.E. [9] say that dwarf smut is typical of areas with early and steady snow cover.

In the former Soviet Union, foci of winter wheat dwarf smut were found in Armenia (1947), Stavropol Krai (1957), Chechen-Ingushetia (Kurchaloyevsky district), Azerbaijan (Khanlar district), Alma-Aty (Ili district), Khmelnytsky (Chemerovetsky and other areas), Transcarpathian (Irshava district) regions, as well as in Moldova (Balti and Kalaram areas). Since this disease is difficult to distinguish from solid smut by its external signs, it can be assumed that the area and harmfulness of this species of fungus have not been learnt yet.

During the period from 1991 to 2008, expansion of the dwarf smut in the North Caucasian region reached 5-10% [10]. According to S.G. Lukashina, N.N. Ostapenko, A.A. Kalinina [11], in 2010, in Krasnodar Krai, 5,8% of winter wheat seeds contained dwarf smut spores. The dwarf smut is usually found in farms of piedmont and central zones of the eastern subzone of the region.

According to the official data annually published by the Branch Office of the Russian Agricultural Center for Stavropol Krai as of from 2005 to 2017, the dwarf smut is spreading over the region (Table 1).

TABLE I EXPANSION RATE FOR WHEAT DWARF SMUT IN STAVROPOL KRAI

Year	Expansion index	
	Infection area, thousand ha	*% of the proved area*
2005	0.08	0.003
2006	0.6	0.001
2007	1.5	0.001
2009	N/D	-
2010	N/D	-
2013	0.3	0.03
2014	0.1	0.01
2015	N/D	-
2016	N/D	
2017	0.1	0.0004

Note: 2008, 2011, 2012 – no data

As a rule, the disease is typical of Aleksandrovsky district where there is a natural infectious focus. Thus, dwarf smut is an endemic winter wheat disease for Stavropol Krai.

III. DIAGNOSTIC SIGNS

The causative agent of dwarf smut causes a number of pathological phenomena in infected winter wheat plants. The wheat plants affected by the dwarf smut are highly bushy, forming from 4 to 50 stems. In Severnoye, Aleksandrovsky District of Stavropol Krai, in winter wheat fields, there were infected plants with 13 stems. The plants were short (Fig. 1).

Spikes of infected plants often do not come out of the flag leaf bosom and remain half covered up to their full maturity. Infected ears are slightly shortened, dense; awnings are bent, twisted, and scales are turned so that ears look pinnate. Grapes are shortened. The number of infected ovaries in spikes is 4-7 or more. Accordingly, the number of spike scales increases.

The dwarf smut does not destroy shell and spike parts (pericarp) of the grain. Its bags are smaller (2.9-7.2x2.3-5.2 mm) in size, round or ellipsoid-shaped. Dwarf smut sori discovered by N.V. Repukhova (2005) in Shpakovsky district of Stavropol are almost 2.0-2.5 times larger than those found in Aleksandrovsky District (Severnoye). They are 6,9x4,7 mm and 2.9x2.3 mm in size respectively.

The top of the dwarf smut sori is rounded with remnants of flower stigma in the form of two filiform appendages.

Fig. 1. Dwarfism of plants infected with Tilletia controversa Kuehn. (by A.A. Gavrilov, N.V. Repukhova, and A.P. Shutko, 2006)

Tilletia controversa fungi teliospores formed in smut bags are spherical, ovoid, rarely oblong or ellipsoidal, 19-27 in diameter, 24-32 microns in size. The teliospore shell is light brown with high (1.5–3 μm) and wide (3-5 μm) polygonal meshes on the mesh exospore, with a gel-like transparent sheath 2–4 μm in thickness. Among mature spores, there are hyaline, colorless spores with a smooth or reticulated membrane. Their number is 4-9%, the size is 17-23x12-22 microns (Fig. 2).

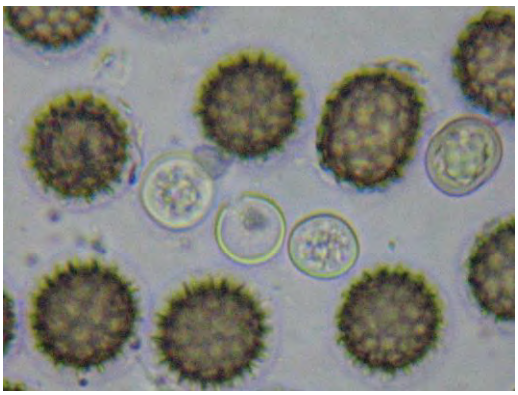

Fig. 2. Spors Tilletia controversa Kuehn. (photo by A.P. Shutko)

In general, in field conditions, the dwarf smut can be unmistakably determined by the sum of these signs. In some cases, it is still difficult to distinguish this disease from solid smut by appearance of infected ears and smut bags. In this case, microscopic analysis is required.

IV. Toxicity of Tilletia Controversa Kuehn.

Many fungi infecting crops are toxic for warm-blooded animals. Therefore, health of farm animals and birds, their reproductive functions, productivity, biological value of the products depend on sanitary conditions of food which is determined by the degree of contamination by pathogenic microorganisms and anthropogenic and natural toxins [15].

In terms of toxicology, Ustilago and Tilletia are of great importance. In some circumstances, food contaminated with these fungi causes severe poisoning in animals. Eating toxic grains causes diseases and deaths during 1-3 days with clinical signs of central nervous system damage (trembling, convulsions, paralysis). For example, in mice, conjunctivitis is followed by rapid breathing. Ten days after, animals refuse to eat and die. Degeneration of all organs except for heart is typical of this disease. Inoculation of medium does not identify causative agents of any disease [16]. When harvesting, grain and straw become infected with spores of the dwarf smut. The food quality is also reduced due to the unpleasant smell and toxic action of smut spores.

V. Phytosanitarian Requirements To Wheat Exported From The Russian Federation To China

According to the Daily business newspaper RBC (rbc.ru), by the end of 2017, China became the second largest buyer of Russian food. China bought Russian products for $ 1.717. Egypt purchased food for $ 1.739 billion.

However, in 1997, China imposed a ban on importation of Russian wheat due to the quarantine dwarf smut of wheat. In 2005, the Russian Federation offered China to buy wheat grown in Siberia, where there is no causative agent of the dwarf smut. According to the results of inspections carried out by Chinese experts in 2006 and 2015, the Siberian Federal District was recognized as free from the causative agent of the dwarf smut. Krasnoyarsk Krai, Altai Krai, Omsk and Novosibirsk oblasts were allowed to supply wheat to China.

On February 26, 2018, the General Administration of Quality Control, Inspection and Quarantine of China allowed importation of Russian wheat from six regions and cancelled the 2016 quarantine requirement. It is specified that wheat importation is allowed from Chelyabinsk, Novosibirsk, Omsk and Amur oblasts as well as from Krasnoyarsk and Altai Krais.

At the same time, the Chinese government put forward additional phytosanitary requirements (the Protocol between the Ministry of Agriculture of the Russian Federation and the Main State Administration for Quality Control, Inspection and Quarantine of the People's Republic of China on phytosanitary requirements for wheat exported from the Russian Federation to the People's Republic of China) involving warranty of absence of 23 types of quarantine objects in wheat. Most of these objects are widespread in Russia (Table 2).

TABLE II Chinese List Of Quarantine Hazardous Wheat Organisms (Protocol On The Phytosanitarian Requirements To Wheat Exported From The Russian Federation To China Of November 1, 2017

Latin name	English name	Location in the Russian Federation
Tilletia controversa Kuehn.	Dwarf smut of wheat	South of the Russian Federation
Trogoderma glabrum Hb	Trogoderma black	Grain-receiving and grain-processing enterprises of the European part of Russia and Western Siberia
Trogoderma variabile Ball.	Trogoderma variable	Southern and middle regions of the European part of Russia and Siberia
Alternaria triticina Prasada	Alternaria	x
Pseudocerco-sporella herpotrichoides (Fron) Deighton.	Pseudosporel stem rot	North Caucasus, European part, North-Western regions of Russia
Ambrosia artemisiifolia L.	Ragweed	Quarantine object which is stenotopic in the Russian Federation
Ambrosia psylostachya DC.	Perennial ragweed	Quarantine object which is stenotopic in the Russian Federation
Ambrosia trifida L.	Richweed	Quarantine object which is stenotopic in the Russian Federation
Avena persica Steud.	Louis oat	South-western regions of the European part, the North Caucasus, the Far East (alien)
Avena sterilis L.	Sterile oat	Crimea (alien)
Bunias orientalis L.	Sweet silique	Everywhere in the Russian Federation
Centaurea diffusa Lam.	Sprawling cornflower	Southern steppe of Russia, Altai Territory, Volga region
Acroptilon repens DC.	Creeping rhodeus	Quarantine object which is stenotopic in the Russian Federation
Cuscuta spp.	Dodder	Quarantine object which is stenotopic in the Russian Federation
Sorghum almum Parodi	Generous sorghum	x
Sorghum halepense (L.) Pers.	Aleppo sorgo	South European part of Russia, Crimea, North Caucasus
Xanthium sibiricum Patrin ex Widd.	Siberian burweed	North Caucasus, Western and Eastern Siberia, the Far East
Xanthium pensylvanicum	Pennsylvanian burweed	Crimea
Xanthium chinense Mill.	Chinese burweed	x
Mayetiola destructor Say.	Hessian fly	European part of Russia (except for the extreme north), the North Caucasus, the south of Siberia and the Far East
Solanum rostratum Dun.	Spiculate nightshade	Quarantine object which is stenotopic in the Russian Federation
Lolium temulentum L.	Darnel ryegrass	European part, North Caucasus, Western Siberia

Note: X – no data

VI. Conclusion

Thus, globalization, as a process of world economic, political and cultural integration requires strengthening of control over expansion of dangerous plant diseases, pests and weeds. This is evidenced by strengthened phytosanitary requirements in some countries (the People's Republic of

China imposed a ban on wheat supplies from the European part of the Russian Federation due to a quarantine object – wheat dwarf smut; Jordan reduced the permissible Fusarium infection rate for wheat to 0,03%) and real environmental disasters caused by invasive species. For example, Cydalima perspectalis which was brought together with planting material to the Black Sea coast of the Caucasus threats Cydalima perspectalis which is an endemic of the the Colchian flora listed in the Red data books of Russia, Georgia and Azerbaijan. Serious environmental consequences cause deaths of chestnut plantations in Russian cities due to penetration of the mineral Ohrid mineral or chestnut mining moths (Cameraria ohridella Deshka et Dimic.). Effective international cooperation can prevent expansion of harmful organisms.

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