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Problems of Crop Production and Plant Protection in the Conditions of Climate Changes in Siberia

N.I. Kashevarov[1], G.M. Osipova[1], L.F. Ashmarina[1], A.A. Maluga[2], O.A. Kazakova[3], Y.S. Skryabin[3]

[1]*Siberian Research Institute of Agriculture of the SB RAS, Novosibirsk*
[2]*Siberian Institute of Soil Management and Chemicalization of Agriculture of the SFNCA RAS, Novosibirsk*
[3]*Novosibirsk State Agrarian University, Novosibirsk, Dobrolyubova Str., 160*

Abstract

This article studies the influence of climate changes on the phytosanitary situation in crop planting in Siberia. The main negative consequences are caused by a decrease in the climatic stability of regionalized varieties and their disease resistance, as well as a deteriorating phytosanitary situation in connection with the creation of favorable conditions for epiphytoty, mass reproduction of pests and the emergence of pests uncharacteristic for Siberia. To reduce the consequences of climate changes, it is necessary to use a complex of adaptation measures, including the increase of plants' stress-resistance, the optimization of the structure of cultivated lands, the creation of resistant varieties, the phytosanitary monitoring of crops, and changes in the agro-landscape zoning of Western Siberia.

Keywords: adaptation, climate change, pathogens, plant growing, plant protection, plant stress, phytosanitary situation, resistant varieties, temperature rise.

Introduction

In the recent decades, interregional climate changes in Russia have been of a clearly pronounced character [1-3]. Thus, Western Siberia experienced a significant increase in air temperature between 1961 and 2009. Warming tendencies are registered mostly in spring, summer and autumn. By the middle of the 21st century, the average annual air temperature in Western Siberia will rise by 3-4℃, while the temperature in the northern European part of Russia is expected to increase by 2-3℃ [4], with a decrease in soil moisture [5].

Some scientists suggest that the zonal climate is being replaced with the meridional one. Wide bands of cyclones moved from west to east (from Siberia to Europe) during the previous climatic epoch. Now weather "moves" along the meridians, i.e. from one pole to the other [6]. Global warming scenarios are also ambiguous: some experts believe that winters will be warmer, while others think that mostly summer temperatures will be influenced, and northern latitudes will be more affected by climate changes [7].

Results And Discussion

The main negative effects of climate changes in Siberia for plant growth are the reduction of climate resilience of recognized varieties and their disease resistance, as well as a deteriorating phytosanitary situation due to the creation of favorable conditions for epiphytoty, mass reproduction of pests and the emergence of harmful organisms uncharacteristic for Siberia.

Currently, there are enough facts about the significant effect of air temperatures on disease resistance genes of plants. For instance, temperatures above 20°C can reduce the resistance of oats with Pg3 and Pg4 genes to stem rust. Higher temperatures increase the lignification of cell walls and make plants more resistant to fungal pathogens [8-9].

Under the influence of high temperatures, plants can change their immune status (http://www.activestudy.info/ustojchivost-selskoxozyajstvennyx-rastenij-k-patogennym-mikroorganizmam) [10-11]. The plants that experienced stress often become more susceptible to pathogens and pests [12-14]. Rising temperatures can make cereal crops more or less susceptible to pathogens, while some cereals become more stable [15-16]. Influenced by increased temperatures, the causative agent of Septoria tritici found in living plants can change the duration of its incubation period and the intensity of infection [9, 17].

To find the ways of changing the phytosanitary situation in growing agricultural plants, scientists should consider the fact that the optimal temperature for most fungi is within 24-28°C, the minimum temperature is 4-8°C, the maximum temperature is 30-35°C (Levitin, 2012). However, smut balls Ustilago avenae prefer the temperature between 50°C and 53°C. Moderately warm winters contribute to the survival of the following genera of fungi: Alternaria, Cercospora, Colletotrichum, Phomopsis, Septoria, Venturia. Unusually warm winters do no harm to the causative agent of stem rust in wheat – Puccinia graminis. Such genera of soil fungi as Pythium, Rhizoctonia, Sclerotinia and others are less affected by climatic factors since they form overwintering structures that protect them from adverse external effects. Warmer summers are favorable for the development of the following types: Podosphaera, Sphaerotheca, Uncinula and Ustilago, as well as the spread of Fusarium graminearum producing mycotoxins dangerous for humans and animals [18]. At the same time, one can expect the reduction of harmful effects of Fusarium culmorum and Microdochium nivale that need cool weather for their development. High temperatures and arid conditions make barley and rye more sensitive to rhynchosporium, increase the harmfulness of powdery mildew on gray breads and worsen the negative effects of oats leaf stripe on oats [8-9]. Global warming causes the lowering harmfulness of the late blight disease of potatoes since its causative agent requires cool and wet weather conditions for its development.

Rising temperatures cause the mass reproduction of pests. The optimal temperature of their vital activity is unstable and influenced by other factors [19]. However, the most favorable temperature is about 26°C characterized by an average development rate, the maximum fertility and the minimum mortality. Therefore, one can expect the growth of harmful insects, as well as the increase in their distribution areas (for example, the Colorado potato beetle).

An increase in soil temperature, long periods of drought and heavy rainfalls affect both the structure of soilborne microbiota and its metabolic activity. Hot and dry springs or summers provide favorable conditions for soil fungi that are the causative agents of root rots. It is known that soil warming increases the frequency of horizontal gene transfer among bacteria. It has been experimentally shown [20] that an increase in temperature from 20°C to 30°C enhances the frequency of conjugation and gene transfer between Escherichia coli and Rhizobium meliloti. If the concentration of CO_2 increases, nitrate content in soil decreases. At the same time, mycorrhizal intensity increases by 47%, and the number of nitrogen-fixing bacteria rises [21].

Climate changes also undermine the effectiveness of plant protection means. Extreme temperatures, wind, precipitation and other environmental factors can affect the efficiency of fungicides and insecticides, their phytotoxicity, soil dynamics, sedimentation, leaf absorption and drug degradation, which is important to take into consideration in the conditions of global warming. In this case, one of the ways to improve the effectiveness of compounds is to optimize the time pesticides are used. The influence of agro-climatic conditions on the effectiveness of pesticides is confirmed by studies conducted in different soil and climatic zones of Russia. The largest wheat harvest was gathered in case of optimal plant moisture, while insufficient or excessive watering led to negative effects [21, 22].

The latest plant protection systems often include biological drugs based on bacteria and fungi. However, they can lose their effectiveness at higher temperatures. In the case of climate warming, it is necessary to create microbiological compounds based on the agents developing high activity at elevated temperatures.

CONCLUSIONS

Taking into account the above-mentioned facts about climate changes, the authors of the article suggest undertaking the following adaptation measures:

1. To adapt the species composition of crops to climate changes by increasing their stress tolerance and optimizing the structure of cultivated lands. In recent years, scientists have been paying much attention to stress reactions associated with “cross” (conjugate) plant resistance. The latest studies have revealed that the response of plants to two or more stressors is unique and cannot be extrapolated to the reaction of plants to an individual stressor. The joint action of various stressors leads to complex responses of plants since they are controlled by different and sometimes even opposite signaling pathways that can either interact with or inhibit one another. The current and predicted climate changes unite a set of stressors affecting the growth, development and productivity of crops. Global annual losses caused by various stressors are estimated at billions of dollars.

Scientists conduct numerous studies on the influence of stressors on different plants mainly in laboratory conditions. Despite the high productivity, stability and precise modeling of laboratory experiments, the conditions of any particular field differ from the controlled conditions created in a laboratory. To solve this problem, scientists develop a number of approaches aimed at not only changing the species composition of cultivated plants, new varieties, technologies and remedies, but also at choosing a combination of specific stressors to study them under controlled conditions. While combining different stressors, researchers set the task of identifying specific molecular pathways that could improve the stress tolerance of plants in the field.

2. To create and rapidly implement new varieties having broader adaptive capabilities and the necessary properties for a particular soil and climate zone, including low-prevalence and non-traditional for Siberia crops. The use of heterogeneous populations containing varieties resistant and tolerant to abiotic and biotic factors reduces the risk of epiphytoties in farming ecosystems.

3. To constantly monitor the emergence of new plant diseases and harmful phytophages that are more typical of northern areas. There is a need for a detailed study of their bioecological features in order to forecast the development of these species in new environmental conditions.

4. To change the agro-landscape zoning of Western Siberia, the structure of cultivated lands and technologies for crops production and storage due to the introduction of new adapted (stress-resistant) varieties and changes in the phytosanitary situation of crops, soil structure and soil microbiota.

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