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Research Article

THE INFLUENCE OF PHYSIOLOGICALLY ACTIVE SUBSTANCES ON THE DEVELOPMENT OF FUNGOUS DISEASES OF WINTER WHEAT

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ABSTRACT

The paper presents data on the studies of the influence of growth regulators on the infection rate of winter wheat. It is determined that the effectiveness of growth regulators largely depends on soil-climatic factors and weather conditions. To reduce the level of infection by parasitic diseases and the negative impact of environmental factors, it is recommended spraying winter wheat crops with DKM-1, GK-Cu, GK-Zn, DAG-1, DAG-2 preparations. The preparations can be used for preventive purposes to reduce the level of infection of winter rye by fungal parasites. The stimulating effect of soluble silicon is determined, which is probable due to increased consumption of phosphorus and molybdenum, as well as the transfer of manganese in plant tissues.

INTRODUCTION

Wheat in Central Asia is one of the main cereal food crops. At the same time, winter wheat has a number of phytopathogens, the development of which significantly limits the potential of modern intensive varieties of it. The most harmful are yellow and brown rust and powdery mildew - narrowly specialized obligate parasites. The damage from rust and powdery mildew can reach 15-25%.

Against the backdrop of intensive technologies of winter wheat cultivation, their harmfulness increases and crop losses may increase by another 5-10% [1].

Brown rust reduces the endurance of plants to unfavorable stress factors, leads to premature leaf withering and the cessation of photosynthesis, to the decrease of the resistance capacity of young crops and the loss of the harvest [2]. Powdery mildew is ubiquitous. The leaves of the diseased plants are covered with a white mealy conidial sporulation of the fungus, turn yellow and, if damaged severely, die off. Black point formations - the pathogen cleistothecium may appear on the powdery plaque (marsupial stage) [3].Rust fungi in Central Asia are often found on wild grasses, some of them are natural reserves of pathogens for agricultural plants [4]. Chemical preparations are usually used against rust and powdery mildew.

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However, having effective fungicidal properties, they can have an adverse effect on the growth and development of cultivated plants, in particular, the winter wheat. Chemical protection of plants is a source of serious pollution of the agricultural ecosystem, water and food products. While biologically active substances provide the most permanent, long-lasting and safe protective effect. They optimize the functional state of plants and, thereby, induce a high level of resistance to pathogens and other unfavorable environmental factors [5, 6].

According to A.O. Marchenko [7], the main factor controlling the realization of the morphogenetic potential of the organism are phytohormones. In certain ratios and concentrations, they are responsible for the expression of the "necessary" genes and, consequently, the realization of the genetic program of the plant. Obviously, over time, the list of regulators and phytohormones will increase. This will expand our understanding of how the hormonal system regulates the ontogeny of plants and how it participates in the response of plants to various external influences.

As it turned out, very many plant parasites of both fungal and bacterial origin use different phytohormones, which they actively synthesize in order to launch a "chemical attack" on the host plant [8, 9, 10]. Pathogens, in the course of complex evolution, have developed a set of adaptations to obtain necessary substances from plant tissues. However, the introduction of infectious structures violates the integrity of the plant. Obligatory parasitism, in its manifestation, is somewhat similar to abiotic stress, which does not kill the plant, but forces all systems to mobilize for increased activity for reparation. Dyakov Y.T. [11] indicates the activation of the synthesis of stress metabolites at the first stages of pathogen introduction. The plant resists the introduction of the pathogen regardless of virulence, but when it is susceptible to the pathogen, the response to infection is generally lethargic and the parasite manages to form infectious hyphae and give offspring.

The introduction of the pathogen causes a cascade of protective reactions in a stable plant, leading to localization of the focus of infection and the emergence of systemic acquired resistance in the plant organism. Its formation is associated with the production of signaling molecules in infected tissues and their translocation to uninfected parts of the plant, where they induce protective reactions, contribute to an increase in resistance to secondary infections [12].

One of the inducers of the signal of pathogen introduction is arachidonic acid, which is part of the cell walls of hyphopathogenic fungi [13]. Numerous secondary metabolites are known to protect higher plants from harmful organisms. Some of these compounds are present in healthy tissues, others appear in response to infection. A significant part of the protective substances belong to phenolic compounds [14]. Oxycoric acids - n-oxycinnamic (n-coumaric), coffee, ferulic and synapic are present in plants, both in free and in bound form. They affect the growth processes, and their derivatives - oxycinnamic alcohols - the initial components in the biosynthesis of lignin [15]. Lignification of the cell walls creates a mechanical barrier to the penetration of the infection.
Silicon plays an important role in the initial stages of the infectious process. H. Kuno *et al*. [16], using X-ray microanalysis, showed the accumulation of silicon and calcium in papillae in the sites of interaction between barley epidermis and powdery mildew. Penetrating plant tissues that have a system of absorption and metabolism of silicon, rust significantly enhances its absorption from the soil solution. In this case, silicon is detected in the mesophyll cells in contact with the fungus, as well as in the boundary zone between the fungal haustoria and the cytoplasm of the host [17].

Thus, the purpose of exogenous growth regulation is to "distract" the plant from the hormonal action of the pathogen, increase the plant's overall resistance to biotic stresses, mobilize plant immunity by elicitors, which helps to prevent or reduce infection, and the introduction of readily available silicon, will allow the plant to quickly create a mechanical barrier to infection.

METHODOLOGY

A small-plot experiment was laid on weakly saline soil by the method of randomized repetitions, in a fourfold repetition. The total area of the plot was 7.2 m^2 (3.6 m *x* 2 m), the registration area of the plot 1 m^2. The precursor of winter wheat in the experiment was cotton of the second year of use.

After cutting the experimental sites of perennial grasses and stubble cleaning, plowing with skimmer was performed. In the experiment, the background dose of nutrients was increased to N100 P60 K60 by additional addition of a mixture of phosphor nutrients (N13 P19 K19) and ammonium nitrate (N 34) into the spring top dressing. The sowing was conducted on September 25 in 2016 and 2017, and on the 4th of October, in 2017-2018. The seeding rate is 4 million pieces per hectare. The variety of winter wheat is Dustlik.

The treatment of winter wheat plants with preparations was carried out at the end of tillering - the beginning of the outlet into the tube, with the knapsack sprayer in the evening, using the appropriate doses of the preparations.

Preparations of DKM-1, DAG-1, DAG-2, GK-Cu, GK-Zn were used at a concentration of 1x10-6 mol/l, the concentration of sodium silicate was 5% (selected in the course of preliminary studies). Control plots were sprayed with water.
The diagnosis of infection of plants was carried out in the phase of the dairy state of the grain. From each replication of the studied variant, 100 plants were taken, and the three upper leaves were examined. In order to determine the rate of contamination with rust, the number of pustules at the die-cut was counted by counting them on 1 cm^2 of the leaf surface. The diagnosis of infection with powdery mildew was carried out according to the percentage scale [18].

Preliminary examinations, conducted on the plots before treatment with drugs, did not reveal foci of rust and powdery mildew. There were necrotic spots and epidermis on the overwintered leaves. The ends of the leaves were dry, with visible traces of snowy mold. There was minor damage by leaf fleas and thrips on the newly grown leaves. The pustules of brown rust and powdery mildew were diagnosed during the phase of the entry into the tube on all plots, but the degree of lesion remained at a low level.

RESULTS AND DISCUSSION

H. Massel [19] and Yu.B. Konovalov and co-authors [20] propose to conduct selection not on the basis of resistance to infection by a pathogen, but on the basis of tolerance to the disease, i.e. ability to keep the crop at a high level in the epiphytotytic years.

This strategy is similar to the use of economic thresholds of damage, in exchange for costly eradication treatments. Regulators of growth, in most cases, have not fungicidal, but fungistatic activity. They do not provide resistance to the pathogen, but contribute to reducing the severity of the disease to a safe level.

Treatment with drugs was carried out until the third leaf from the ear extended. Thus, we are talking about a comparison of the systemic effects of drugs. The infection of leaves of different ages changed significantly.
The lower leaves experienced an infectious load for a longer time. As for the time of the survey, their infection, as a rule, was higher.

However, we noticed that the number of rust pustules on the second leaf from the ear on the control variants was lower than on the flag leaf throughout the years of research. This fact is not related to precipitation (meteorological conditions during the years of study varied significantly) or sporulating activity of pathogens (at the time of appearance of the flag leaf, the second from the ear was already experiencing an infectious load). A probable explanation may be the emergence of acquired system stability in plants at the time of the appearance of the second leaf and a decrease in age resistance to the appearance of a flag leaf [21]. The reason can also be the projected location of the tiers of leaves and uneven deposition of the spore material related to it. Therefore, it is more correct to compare the change in infestation to control within a single tier of leaves.

The data given in the table show that in 2015, spraying of winter wheat with DKM-1 (copper component of glycyrrhizic acid with technical glycyrrhizic acid) and sodium silicate played an important role in reducing infection with powdery mildew. So the infection of the third leaf from the ear fell by 17 and 16%, the second by 7 and 13%, respectively. Treatment of plants with DAG-1 reduced the degree of damage to the third leaf from the top by 12%.The studied drugs significantly affected the infection with brown rust. Comparing the change in infestation of leaves of different ages to the control, one can judge the rate of response to the drug and the prolongation of its action. So DAG-1 affected the infestation of the third leaf from the ear, which had appeared before treatment, reducing the number of rust pustules by 59%. DKM-1 also showed high efficiency on older leaves. The number of pustules on the third leaf on top decreased by 86%. Reduction of the infection of flag and subflag leaves was significant, but notably less 25 and 23%, respectively.

Sodium silicate has consistently reduced the infection of leaves of different ages. The number of pustules on the third leaf decreased by 54, on the second by 38, and on the flag leaf by 44%. It is very likely that the availability of the application allowed to absorb silicon for a longer period or to reutilize the accumulated amount in the plant.

In the plots where DAG-2 was applied, the stronger the decrease in the number of rust pustules the older the leaf was as compared with the processing time: on the third leaf from top by 24 %, on the second by 31%, and on the flag leaf by 38%. GK-Cu significantly reduced the infection of leaves that appeared closer to the time of treatment: the third leaf from the ear by 43%, the second by 38%, while the flag leaf only by 25%. The preparations practically did not affect the width of the leaf blade. We can note an increase of this indicator in the flag leaf by 15% when applying GK-Zn and sodium silicate.

DKM-1 did not affect the change in the number of rust pustules, but actively reduced the contamination with powdery mildew. DAG-1 reduced the degree of rust damage to the third leaf from the ear, significantly reducing contamination with powdery mildew. In this case, a significant aftereffect of the drug was observed. The actions of sodium silicate and DAG-2 were similar.

Significantly reducing the infestation of the subflag leaf with powdery mildew, GK-Cu increased the infection with rust. GK-Zn significantly reduced the infection with powdery mildew, however, it increased the intensity of infection with rust.The preparation DKM-1 turned out to be the most effective immunocorrector. Spraying contributed to a decrease in the degree of infection of the flag leaf with the mildew by 10 %, the second leaf from the ear by 28%, the third by 26%. The number of rust pustules on the third leaf from the top has decreased by 88%. In 2017-2018 the effect of growth regulators on pathogenesis was somewhat different from previous years, but there were earlier patterns, too. In these years there was less precipitation during the period of active vegetation than in previous years. It should be noted that there was a decrease in the width of the leaf blade of all tiers.The number of rust pustules on the third leaf from the ear decreased, however contamination with powdery mildew increased. This fact is associated with the need for drip-liquid moisture to germinate uredospore - rain or dew. Conidia of powdery mildew can germinate in the absence of liquid moisture. There is evidence that outbreaks of powdery mildew are confined to dry periods, when plants are in a weakened state [22]. Spraying plants with DAG-1 and GK-Cu reduced the width of the leaf blade of all tiers that year, while the DKM-1 and DAG-2 preparations reduced the third leaf from the ear. Sodium silicate, on the contrary, increased the width of the third leaf from the top by 20%, whereas the GK-Zn did the same with the subflag leaf by 28%. Preparations: DKM-1, sodium silicate, GK-Cu, DAG-1, more strongly reduced the level of infection with powdery mildew of those leaves that appeared closer to the time of treatment. DAG-2 intensified the infection of the flag leaf with powdery mildew. Most likely, in dry conditions, the period of repair process was prolonged in plants of winter wheat, which led to the weakening of pathogenesis in them. In variants of the application of GK-Zn, the degree of infection of plants with powdery mildew was at the control level.

Sprinkling of plants with sodium silicate contributed to a decrease in the number of rust pustules on the third leaf from the ear by 55%, on the second by 72%, and on the flag leaf by 82%. In the variants in which GK-Zn was used, the number of rust pustules on the flag sheet decreased by 58, on the second from the ear by 61%. GK-Cu stably reduced the number of rust pustules on all tiers by 26-28%. The effect of DKM-1 and DAG-1 preparations was equivocal. On the third leaf from the ear, there was a significant decrease in the number of pustules by 42 and 45%, respectively. On the subflag leaf the resistance fell sharply, whereas the number of pustules increased by 44 and 61%. On the flag leaf, the number of pustules decreased again by 39 and 33% compared to the control. It can be assumed that immediately after the treatment of plants, the preparations mobilized a protective system with the help of accumulated energy. Then came the phase of remission, and unfavorable conditions did not allow plants to quickly restore the reserve of forces resulting in a decrease in immunity.

As in previous years, GK-Cu more strongly reduced the infection of the leaves of the upper tiers, which appeared after the processing date. Its effect on the flag sheet was more significant. The number of rust pustules at the most photosynthetically active center decreased by 36%. Summarizing the data, it can be noted that sodium silicate and DKM-1 decreased more strongly the infestation of winter wheat plants with brown rust and powdery mildew. The undoubted participation of silicon in the pathogenesis of parasitic diseases is confirmed by many researchers. Silicon impregnates and hardens plant tissues, reduces water loss and slows the development of fungal infections.

The stimulating effect of soluble silicon is probably associated with increased consumption of phosphorus and molybdenum, as well as the transfer of manganese in plant tissues. It is assumed that silicon enhances phosphorylation and synthesis of sugars, which increases the energy input for metabolic processes and increases the intensity of plant growth [23, 24]. GK-Cu significantly reduced the number of rust pustules on the flag and on the third leaves from the ear and the percentage of powdery mildew infection of the second and third leaves from the apex.

CONCLUSION

The study of the effects of growth regulators in the field environment often leads to ambiguous results, which cause many contradictions between the data of different researchers. The effectiveness of growth regulators largely depends on the soil-climatic factors of the region, the weather conditions in the years of the experiment. Due to polyfunctionality, exogenous phytohormones can influence the course of physiological processes, increase or decrease plant growth, and change its tolerance to the phytopathogen.

To reduce the infection rate with parasitic diseases and the negative impact of environmental factors, we recommend spraying winter wheat crops with DKM-1 GK-Cu, GK-Zn, DAG-1, DAG-2 preparations. However, the positive effect of the drugs studied is limited by fungistatic activity. Preparations can be used for preventive purposes to reduce the rate of infection of winter rye with fungal parasites.

The exceptionally positive role of sodium silicate indicates the need for a broad study of silicon fertilizers and their introduction into the production of grain crops. The ambiguity of the results of the use of GK-Cu and GK-Zn concerning the contamination of rye also requires further study of these preparations in this aspect.

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