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Forecasting of epiphytotic diseases in agricultural crops by the example of Northern Kazakhstan and their impact on economic growth

Pronóstico de las enfermedades epifíticas en los cultivos agrícolas: ejemplo del norte de Kazajstán y su impacto en el crecimiento económico

Aigul Toktarbaevna OLEINIK 1; Galina Ivanovna ROZHKOVA 2; Xenia Petrovna OVCHINNIKOVA 3; Gulnara Toktarbaevna MOLDAKHMETOVA 4

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Contents

ABSTRACT:

This article presents three-year (2014-2016) results that describe the dependence of the development of dangerous diseases in spring wheat crops on weather conditions in the Kostanay region (Kazakhstan) and the positive role of preventive fungicidal treatments. The research object included industrial crops as well as spring wheat samples affected by pathogens: brown rust (*Puccinia recondita Rob. ex Desm f. sp. tritici Erikss. et Henn*), stem rust (*Puccinia graminis Pers f. sp. tritici Erikss. et Henn*) and septoriosis (*Septotria tritici, Septotria nodorum*), collected in the territory of the Kostanay region. Observations over the dynamics of the development of diseases were carried out by the main phases of the development of spring wheat. During the period 2014-2016, on the experimental field of the Kostanay branch by small-scale experiments the

RESUMEN:

Este artículo presenta resultados de tres años (2014-2016) que describen la dependencia del desarrollo de enfermedades peligrosas en los cultivos de trigo primaveral en las condiciones climáticas de la región de Kostanay (Kazajstán) y el papel positivo de los tratamientos fungicidas preventivos . El objeto de investigación incluyó cultivos industriales así como muestras de trigo de manantial afectados por patógenos: roya marrón (*Puccinia recondita Rob. ex Desm f. SP. tritici Erikss. et Henn*), roya del tallo (*Puccinia graminis Pers f. SP. tritici Erikss. et Henn*) y septoriosis (*Septotria tritici, Septotria nodorum*), recogido en el territorio de la región de Kostanay. Las observaciones sobre la dinámica del desarrollo de las enfermedades se llevaron a cabo por las principales fases del desarrollo del trigo de manantial. Durante el

effect of fungicides with various active substances on the restraining factor of dangerous diseases of the Kostanay region was studied. The spread and development of diseases was determined by the method of K.M. Stepanov and A.E. Chumakov (1972). Small-scale experiments confirmed the positive preventive role of fungicidal treatments in the years with factors contributing to the development and spread of diseases. The main objective of plant protection measures is to reduce crop losses based on an integrated system of protective measures that are safe for humans and the environment.
Keywords: Brown rust, fungicides, septoriosis, spring wheat, stem rust.

período 2014-2016, en el campo experimental de la rama de Kostanay por experimentos en pequeña escala el efecto de fungicidas con varias sustancias activas en el factor de restricción de enfermedades peligrosas de la región de Kostanay fue estudiado. La propagación y desarrollo de enfermedades se determinó mediante el método de K.M. Stepanov y A.E. Chumakov (1972). Los experimentos en pequeña escala confirmaron el papel preventivo positivo de los tratamientos fungicidas en los años con factores que contribuyen al desarrollo y propagación de enfermedades. El objetivo principal de las medidas de protección de las plantas es reducir las pérdidas de cultivos basadas en un sistema integrado de medidas de protección seguras para los seres humanos y el medio ambiente.
Palabras clave: herrumbre marrón, fungicidas, septoriosis, trigo primaveral, roya del tallo.

1. Introduction

Currently, due to a new direction in agriculture – the moisture-saving technology of cultivation of grain crops – and its positive influence on the increase of soil fertility, there is also a negative tendency of accumulation of pests, weed seeds, infectious diseases caused by pathogenic fungi in the surface soil. The loss of harvest from a complex of harmful species in the cultivation of crop production is estimated at 35-50% (Vinogradov, 1987; Toropova, 2002). The fight against diseases is one of the main tasks of plant protection, since in the period of epiphytoty the yield of resistant species only from stem and brown rust can be reduced by 20-30%, and that of vulnerable species – by 50-70% (Koyshybayev, 2002).

The saturation of rotations with grain crops, mainly wheat, and their cultivation according to the accepted conservation cropping system, providing stubble conservation, contributes to the accumulation and preservation of helminthosporium-septorian infection (Oleinik et al., 2015a). All this leads to the need to use highly effective and qualitative plant protection means.

The main reasons for the development of diseases in spring wheat crops are:

- weather conditions of the growing season;

- absence of seed dressing;

- monoculture;

- planting of species vulnerable to diseases;

- disregard of fungicidal treatments during the epiphytoty of dangerous diseases of spring wheat (Lysenko and Efimov, 2007).

One of the main tasks is to determine in time the likely occurrence of diseases and to stop their development (spread) at a level that does not threaten significant crop losses. The main method of stabilizing the phytosanitary situation in spring wheat crops is to monitor the development of disease pathogens.

The dangerous diseases of spring wheat, which were transformed into epiphytoty in 2016 and caused crop losses up to 40% in the Kostanay region, were septoriosis *(Septoria nodorum)*, brown rust (*Puccinia recondita Rob. ex Desm f. sp. tritici Erikss. et Henn*) and stem rust (*Puccinia graminis Pers f. sp. tritici Erikss. et Henn*).

2. Method

Route studies were conducted from 2014-2016 in three natural-economic zones of the Kostanay region of Northern Kazakhstan by the following districts: Mendykara district (1st zone); Kostanay, Karabalyk and Fyodorov districts (1st-2nd zone); Taran district (2nd-3rd zone) (Strukov et al., 1967).

The research object included industrial crops as well as spring wheat samples affected by pathogens: brown rust (*Puccinia recondita Rob. ex Desm f. sp. tritici Erikss*. *et Henn*), stem rust (*Puccinia graminis Pers f. sp. tritici Erikss*. *et Henn*) and septoriosis (*Septotria tritici, Septotria nodorum*), collected in the territory of the Kostanay region. Observations over the dynamics of the development of diseases were carried out by the main phases of the development of spring wheat (ZADOKS et al., 1974).

The soil of the 1st-2nd zone includes ordinary and southern heavy loamy chernozem. The microrelief of the investigated fields is equalized, with the slightly acidic reaction of the soil solution pH of 7%.

The soil of the 3rd zone is dark chestnut sandy loamy. The observed fields are characterized by the relief with ravines and the reaction of soil solution pH of 6.5%.

In laboratory conditions for the phyto-analysis of seed material by the roll method (Toropova and Kirichenko, 2012) spring wheat of the Omskaya 36 variety was used, which was spread in the Kostanay region.

During the period 2014-2016, on the experimental field of the Kostanay branch by small-scale experiments the effect of fungicides with various active substances on the restraining factor of dangerous diseases of the Kostanay region was studied. The spread and development of diseases was determined by the method of K.M. Stepanov and A.E. Chumakov (1972).

The scheme of the experiment is as follows.

The sowing rate of spring wheat is 120 kg/ha. Sowing was continuous and carried out with a cultivator seeder SKP 2.1 (Omichka) to a depth of 6 cm. The size of the plots: length – 30 m, width – 20 m, in 4 replicates.

Treatment with fungicides was carried out in the phase of output of the flag leaf by a hand-held sprayer Oasis with a working width of 3 m, the flow rate of the working fluid was 200 l/ha. The effect of fungicides with various active substances was studied as the phytopathogen populations developed when the first signs of diseases appeared. Control plots were sprayed with water.

The following active substances were used: Flutriafol 250 g/l (0.5 l/ha); Pyraclostrobin 62.5 g/l + Epoxiconazole 62.5 g/l (1.5 l/ha); Spiroxamine 250 g/l + Tebuconazole 167 g/l + Triadymenol 43 g/l (0.6 l/ha).

The problem of the impact of climatic conditions of Northern Kazakhstan on the cultivation of crops is always at the center of the attention of science, having an influence on the productivity and outbreaks of diseases. In order to properly assess the situation with regard to the probability of outbreaks in spring wheat crops, one should take into account the complex evaluation of the developing annual weather conditions, by the ratio of heat and moisture.

The precipitation rate in May 2014 was 13.5 mm, compared with the average long-term data, with a shortfall in precipitation of 22.5 mm. The air temperature was 3.4°C above the average annual indicator of 13.7°C.

In June, there was also a shortage of precipitation, compared with the long-term data (35.0 mm), amounting to 16.1 mm. For spring crops, the critical period with regard to the lack of moisture is the heading phase – earing. The air temperature was on average 21.2°C, which is 1.2°C above the norm. In July, the temperature varied over the decades from 14.5°C to 21.1°C; the precipitation rate was 107.5 mm, which almost twice exceeded the average annual rate (56.9 mm).

August is marked as dry and hot, which allowed the harvesting campaign to be completed on time and without losses.

The sowing campaign in May 2015 was conducted with abundant precipitation, exceeding by 2.3 times the average annual indicator (36 mm), and lasted until June 12. In June, the precipitation rate in the second and third decades also exceeded the norm by 4.7 mm and 3.7 mm.

The monthly average for July was less than the average annual indicator (56 mm) by 8.1 mm, but in the second quarter the precipitation rate was higher than the decade indicator by 7.3 mm. The alternation of precipitation during June and July with warm sunny days (20.2-22.2°C) had a beneficial effect on the growth and development of spring wheat and provoked the development and spread of diseases.

In August, precipitation was recorded on August 2, 6, 10 and 11, with a decrease in daytime and night temperatures to 13-19°C. The temperature drops caused morning fog and abundant dew, which is favorable for the development of phytopathogens.

The spring of 2016 was favorable for the growth of spring wheat in the Kostanay region, and the spring moisture reserve in the soil was at a fairly high level. The precipitation fallen from January to April inclusive exceeded the average annual indicator by 169.7%. A good moisture supply contributed to the development of the vegetative mass of crops.

In the second decade of June, there was abundant precipitation, which was 5.76 times higher than the average annual indicator (8 mm). During the whole month, there were thunderstorms, hail in places and squall wind intensifications at an average temperature of the month of 21.6°C by zones at the average annual level. June precipitation and air temperature provoked an increase in the development of septoria spots.

The monthly precipitation norm in July exceeded the average annual indicator (56.0 mm) by 2.5 times at an average monthly temperature of 20.3°C. Such a temperature regime turned out to be favorable for the manifestation and development of rust diseases in crops.

In August, for 23 days daytime temperatures stayed above 30°C, and night temperatures – from 25°C to 31°C, which stopped the further spread of diseases in crops.

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3. Results and Discussion

The production of consistently high yields primarily depends on qualitative seed materials. Seeds can be the sources of retaining the infection of wheat septoriosis in addition to stubble residues. In the laboratory of the Kostanay branch, an analysis of the phyto-examination of seeds was carried out by the roll method in order to identify the causative agent of the disease and the degree of infection of the crop seeds in 2013-2016 from the study areas of the region (Table 1).

Table 1. Infection of seed material of the Omskaya 36 variety

Yield, years*	Laboratory germination, %	Septoriosis, %	Complex of diseases, %	
			Alternaria blight	Helminthosporium blight
2013	93,50	1,7	14,7	4,5
2014	82,75	4,5	20,5	10,5
2015	89,50	0,5	7,4	8,2
2016	40,75	6,0	2,25	3,25

Note: *Data are taken from laboratory reports of the Kostanay branch

The greatest effect of septoriosis on crop seeds was observed in 2014 and 2016. The development and further infection of seeds was influenced by weather conditions with increased precipitation in July, exceeding the average annual rate by 1.9 times in 2014 and by 2.5 times

in 2016, and moderate temperature, as well as ignoring fungicidal treatments during the growing season.

Based on the analysis results, recommendations were made for obtaining healthy spring wheat sprouting by agricultural producers.

Sharp temperature contrasts in Northern Kazakhstan – cold winter and hot summer with alternating precipitation deficit and fallout, exceeding the average long-term indicators – as well as a high saturation of crop rotations with wheat leads to the growth of crop damage by the most harmful diseases: brown and stem rust, leaf patches, virus diseases (Oleinik et al., 2015b).

Conducted monitoring in the Kostanay region showed that the incidence of septoriosis is observed annually and depending on weather conditions in the region's districts, leaf damage ranges from 10-25% to 60%.

The manifestation of brown rust in 2014 was observed in the second decade of July (the beginning of earing, complete graining). After heavy precipitation in the region leaf damage was 1% to 5%.

In the phase of grain milky ripeness, there was an increase in the development of the disease in Mendykara, Kostanay, Fyodorov and Karabalyk districts (1st-2nd zone) after local precipitation, and the damage to the leaf surface was 50-75%. From stem rust to the phase of milky-wax ripeness, the damage to the stems varied between 10-20%.

In 2015, a routine survey conducted in the tillering-tubing phase showed the widespread presence of leaf septoriosis in spring wheat crops. The development of the disease was affected by the weather factors of the first and second quarters of June as well as the precipitation exceeding the average annual indicators by 1.6 and 1.2 times at an air temperature of 21.2-24.5°C. The degree of the development of leaf septoriosis varied from 1% to 15%, its spread – 25%. During the flowering phase of the crop, the intensity of the development of septoriosis reached 15% to 25%, its spread – 60%, on average, less often on the upper layer of plants. The beginning of the development of brown rust to 1% on the lower layer was noted.

In addition to the previously identified diseases in the filling phase – grain milk ripeness – the beginning of the development of stem rust from 1% to 5% was noted. The intensity of brown rust increased to 50%. The maximum development and spread of septoriosis and rust diseases was found in Kostanay, Karabalyk and Fyodorov districts, minimal – in Taran district of the Kostanay region.

The aggressiveness of pathogens increased due to weather conditions in 2016 and affected the early development of septoria spots in the 3rd phase of the leaf – tillering and the beginning of tubing. The degree of development varied from 0.5% to 0.75%, its spread – from 37.5% to 100%. Single pustules of brown rust were found in Karabalyk and Fyodorov districts.

According to the route survey in the Kostanay region, in the earing-flowering phases the spread of septoriosis was up to 100%, with the intensity of the lesion of 30% to 60%, and brown rust on the middle layer of plants and the flag leaf – from 10% to 35%, with the spread of 60-100%, depending on the location of the region's districts.

Surveys carried out in the phases of grain filling and milky ripeness revealed the epiphytotic development of leaf septoriosis of 40-96% and brown rust of 35% to 100%. In addition, the septoriosis of the spike and the pustules of stem rust began to be developed to 7.5%. The route survey in the phase of grain wax ripeness showed the spread of septoriosis of the spike to 100% with the development rate of 1.25-10% and the development of stem rust from 22.5% to 68%.

According to the long-term studies in Northern Kazakhstan, the development of epiphytoty and brown rust in spring wheat crops is observed in the tubing-earing phase during an increase in precipitation by 1.2-2 times in relation to the average annual rate (Koyshybayev, 2002). The intensity of the development of rust diseases is favorable at the alternating air temperature of

20-25°C and warm short-term precipitation. With the development of septoriosis in the tubing phase – the beginning of flowering from 1 to 10%, it is necessary to carry out protective measures with fungicides (Sanin, 2016).

At the time of the application of fungicides, the degree of the damage to leaves and stems on the experimental field was determined daily by international scales (Peterson et al., 1948; James, 1971).

The prevalence of leaf septoriosis varied from 20% to 45% over the years, and the intensity of plant damage was 15-20%; brown rust varied from 3% to 30% with the intensity of the lesion of 0.3-25%; stem rust – 25-65% with the intensity of damage of 15-40% (Table 2-3).

Table 2. Manifestation of diseases before the application of fungicides in the phase of development of the flag leaf on spring wheat (Kostanay region, Kostanay district, Experimental field of Kostanay branch, 2014-2016)

Variant	Disease											
	Leaf septoriosis						Leaf brown rust					
	2014		2015		2016		2014		2015		2016	
	P*	R**	P*	R **	P*	R **	P*	R **	P*	R **	P*	R **
Control, infection on the day of registration (without treatment)	35	18	25	10	25	18	3,8	0,4	27	15	30	25
Flutriafol 250 g/l (0.5 l/ha)	35	21	35	15	20	15	3,2	0,3	25	10	30	20
Pyraclostrobin 62.5 g/l + Epoxiconazole 62.5 g/l (1.5 l / ha)	40	20	45	19	25	18	3,5	0,5	30	20	35	25
Spiroxamine 250 g/l + Tebuconazole 167 g/l + Triadymenol 43 g/l (0.6 l/ha)	30	17	40	18	20	10	5,2	0,8	30	25	30	20

Note: P * – prevalence of diseases, %; R ** – intensity of the development of diseases, %

Table 3. Manifestation of diseases before the application of fungicides in the phase of grain filling and milky ripeness (Kostanay region, Kostanay district, Experimental field of Kostanay branch, 2014-2016)

Variant	Disease					
	Stem rust					
	2014		2015		2016	
	P*	R**	P*	R**	P*	R**
Control, infection on the day of	25	16	35	25	60	35

registration (without treatment)						
Flutriafol 250 g/l (0.5 l/ha)	25	18	35	20	55	30
Pyraclostrobin 62.5 g/l + Epoxiconazole 62.5 g/l (1.5 l / ha)	30	25	30	15	60	40
Spiroxamine 250 g/l + Tebuconazole 167 g/l + Triadymenol 43 g/l (0.6 l/ha)	30	20	25	15	65	40

Note: P * – prevalence of diseases, %; R ** – intensity of the development of diseases, %

The comprehensive development of leaf septoriosis and brown rust amounted to 25% on average over the years, which significantly exceeds the economic threshold of damage by 10%. Therefore, in the years of observation it was expedient to carry out fungicidal treatments on spring wheat.

During the first registration, 10 days after treatment by products with various active substances, the biological efficacy from leaf septoriosis by years was – 57.1% to 85% (2014); 63% to 89% (2015); 50.4% to 86.9% (2016).

On the 20th day after treatment in the variant with the use of Spiroxamine 250 g/l + Tebuconazole 167 g/l + Triadymenol 43 g/l (0.6 l/ha), leaf septoriosis was practically absent, and in other variants it was insignificant.

As a result, the efficacy of treatment against brown rust on the 10th day was 66.7% to 90.7% (2015); 59.2% to 84.2% (2016), and in 2014 treatment was not expedient, in connection with the non-exceeding of the economic threshold of damage. 20 days after treatment, the biological efficacy was 77% to 95%; 73.4% to 96.9% respectively by year. In the control variants, the number of leaf-and-stem diseases grew over the years.

As the efficacy of treatment against a complex of diseases increased, active substances were arranged as follows: Spiroxamine 250 g/l + Tebuconazole 167 g/l + Triadymenol 43 g/l (0.6 l/ha); Flutriafol 250 g/l (0.5 l/ha); Pyraclostrobin 62.5 g/l + Epoxiconazole 62.5 g/l (1.5 l/ha) (Table 4).

Table 4. Biological efficacy of a single application of fungicides for the vegetation of spring wheat in the phase of development of the flag leaf (Kostanay region, Kostanay district, Experimental field of Kostanay branch, 2014-2016)

Variant	Biological efficacy against diseases, %											
	Leaf septoriosis						Leaf brown rust					
	2014		2015		2016		2014		2015		2016	
	10 day	20 day	10 day	20 day	10 day	20 day	10 day	20 day	10 day	20 day	10 day	20 day
Control, infection on the day of	35	70	25	50	28,75	100	5	10	27	50	30	80

registration (without treatment)												
Flutriafol 250 g/l (0.5 l/ha)	63,6	78,9	69,0	83,0	55,6	71,5	-	-	73,1	85,0	65,0	78,7
Pyraclostrobin 62.5 g/l + Epoxiconazole 62.5 g/l (1.5 l / ha)	57,1	69,6	63,0	74,0	50,4	63,7	-	-	66,7	77,0	59,2	73,4
Spiroxamine 250 g/l + Tebuconazole 167 g/l + Triadymenol 43 g/l (0.6 l/ha)	85,0	95,0	89,0	100	86,9	98,0	-	-	90,7	95,0	84,2	96,9

Stem rust appears later than leaf rust and its development is slower. Then, due to weather conditions, within a few days it can spread, capturing all the crops of spring wheat that could be observed in 2014-2016. The biological efficiency during the first registration was 50% to 77%; 58.6% to 85.7%; 52.1% to 77.9% respectively by year.

On the 20th day after chemical treatment, the efficiency was 61% to 86% (2014); 70% to 95% (2015); 66.5% to 91.7% (2016).

After fungicidal treatment with various active substances, spring wheat in the plots remained protected from the disease (Table 5).

Table 5. Biological efficacy of a single application of fungicides for the vegetation of spring wheat in the phase of grain filling and milky ripeness (Kostanay region, Kostanay district, Experimental field of Kostanay branch, 2014-2016)

Variant	Biological efficacy against diseases, %					
	Stem rust					
	2014		2015		2016	
	10 day	20 day	10 day	20 day	10 day	20 day
Control, infection on the day of registration (without treatment)	25	50	35	60	60	100
Flutriafol 250 g/l (0.5 l/ha)	61,0	72,5	69,3	81,2	59,6	72,0
Pyraclostrobin 62.5 g/l + Epoxiconazole 62.5 g/l (1.5 l / ha)	50,0	61,0	58,6	70,0	52,1	66,5

Spiroxamine 250 g/l + Tebuconazole 167 g/l + Triadymenol 43 g/l (0.6 l/ha)	77,0	86,0	85,7	95,0	77,9	91,7

4. Conclusion

Three-year studies have shown that in the Kostanay region spring wheat is affected by a complex of diseases with leaf and stem infection, and brown rust always develops with septoriosis. According to the results of the branch's research in 2014-2015, the development of leaf pathogens was moderate, but the infectious background remained on crop residues, which caused the abundant development of phytopathogens under favorable weather conditions in 2016. In 2016, the complex epiphytotic development of brown rust with septoriosis and the growth of stem rust in the phase of filling and milk ripeness was recorded. Small-scale experiments confirmed the positive preventive role of fungicidal treatments in the years with factors contributing to the development and spread of diseases. When making a forecast for diseases in 2017 and subsequent years, one should take into account the weather forecast for the upcoming vegetation period and the temperature regime. The main objective of plant protection measures is to reduce crop losses based on an integrated system of protective measures that are safe for humans and the environment.

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1. Zhazken Zhiyembayev Kazakh Research Institute for Plant Protection and Quarantine, Zatobolsk, Kostanay Region, Kazakhstan

2. Zhazken Zhiyembayev Kazakh Research Institute for Plant Protection and Quarantine, Zatobolsk, Kostanay Region, Kazakhstan

3. Zhazken Zhiyembayev Kazakh Research Institute for Plant Protection and Quarantine, Zatobolsk, Kostanay Region, Kazakhstan

4. Zhazken Zhiyembayev Kazakh Research Institute for Plant Protection and Quarantine, Zatobolsk, Kostanay Region, Kazakhstan

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[Índice]