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R.M. Ualiyeva*

Toraighyrov University, Pavlodar, Kazakhstan
**Corresponding author: ualiyeva.r@gmail.com*

Comparative evaluation of preparations' fungicidal activity and their effect on pathogenic micromycetes of spring wheat

The growing season of 2022 was characterised by a variety of weather conditions, some of which were unfavourable to spring wheat growth and development. Plants were stressed by daytime temperatures, soil and air moisture, and fungal disease pathogenic impacts. Spring wheat was infected with powdery mildew (Erysiphe graminis), leaf brown rust (Puccinia triticina), and septoria leaf blotch (Septoria sp.). The main fertilizer, foliar dressing, and compounds with regulatory properties in relation to the crop are used to boost yield and improve grain quality. Fungicides such as Varro, Rex Duo and Kolosal Pro are effective for managing spring wheat diseases. The study established the impact of Varro, Rex Duo, and Kolosal Pro fungicides on the reduction of the main spring wheat pathogens. This had an effect on grain quality and yield characteristics. The fungicides (tested under stressful conditions produced by phytopathogens and unfavourable meteorological conditions) enhanced the growth of spring wheat plants and positively influenced yield morphometric parameters, productivity, and grain quality parameters. The most effective agent for controlling diseases of spring wheat is Rex Duo fungicide. The use of fungicidal treatments in combination with fertilizers and plant growth regulators increased yield structure indicators, which resulted in an even greater impact on yield and quality indexes. It was discovered that the use of fertilizers and growth stimulants to crops can be combined with the application of fungicides.

Keywords: spring wheat, phytopathogens, micromycetes, fungicides, fertilizers, growth stimulator, powdery mildew, brown rust, septoria leaf blotch.

Introduction

Plant diseases are one of the main factors leading to the loss of about 20% of the crop. Seed infection occupies a special place among the pathogenic microflora [1]. It is estimated that 60% of all grain crops' pathogens (alternaria, fusarium, smut, and others) are seed-transmitted [2]. The spread of fungal diseases of plants occurs in the form of epiphytosis, which causes the loss of an extremely significant amount of agricultural crops, and is also expressed in the colonization of the soil with fungi that form toxins which affect the quality and productivity of cultivated crops [3]. The fight against pests and diseases of crops should be based on the seed material's phytosanitary state. These findings are justified by the increased level of nutritional components contained in the seeds, which are the optimal nutrient medium for the development of microorganisms that produce mycotoxins [4]. Approximately 50 different microorganisms can be found on seeds. Seed infection with pathogenic microflora occurs at any stage of plant development, both during the growing season and when grain storage is disturbed [5].

In order to reduce plant disease incidences, it is necessary to conduct a phytosanitary examination of seeds [6]. Phytoexamination of seed material makes it possible to assess the level of phytopathogenic load exerted on seeds (as the main source of infection), and to give a quantitative and qualitative assessment of their general condition, as well as their suitability for cultivation [7]. Crops must be treated in order to protect them from pathogenic microorganisms [8]. This fundamental component of crop cultivation technology allows for the protection of the plant against phytopathogens even at the seed stage as well as the eradication of the infection's cause [9].

A wide range of different disinfectants, including one or more active substances, which make it possible to obtain a healthy crop, even taking into account the increased incidence of seed infections, is present on the modern market [10]. At the same time, the degree of effectiveness of certain drugs depends on the nature of the diseases in general as well as their specificity. As a result, the effectiveness of the outcome depends on the selection of the disinfectant, which is made in light of the seeds' phytoexamination [11].

Currently, fungicides, which can both combat infections of phytopathogens and enhance the qualitative attributes of seeds (growth activity, stress resistance to sharp fluctuations in abiotic environmental factors, development of nonspecific immunity), are of significant interest [12]. These drugs are modern highly effective chemical means of protection against phytopathogenic microorganisms. A suitable fungicide should be chosen for each seed lot based on the degree of infection of the seed material and the pathogen composition. The impact of fungal infections is manifested in significant damage to the studied crops at each stage of plant development and production [13]. The evaluation of fungicide effects on seed material enables the identification and control of the safety and quality of food and feed resources, reducing and thereby preventing significant economic losses.

The scientific study's goal is to compare the fungicidal activity of chemical protection agents and investigate their impact on pathogenic micromycetes of spring wheat.

Experimental

In the field conditions, the effect of fungicides on protection against a variety of fungal infections was investigated. The field experiment was conducted in the 2022 growing season on the experimental spring wheat fields of the Zhumabek Agro seed farm, which is located in the steppe zone of North-Eastern Kazakhstan (Pavlodar region).

"Omskaya 35" is a spring wheat variety of foreign selection that was used in the study. The breeder of the "Omskaya 35" variety is FGBNU "Omsk Agrarian Scientific Center" (Russia). The variety is lutescens. Its vegetation period is 87–90 days. Resistant to lodging is moderately drought tolerant. Moderately susceptible to brown rust, susceptible to dusty mildew, strongly susceptible to hard knotweed, stem rust, powdery mildew, root rot. The "Omskaya 35" variety has a high potential yield and forms high-quality heavy grains. Thanks to the high productivity in combination with resistance to diseases and lodging, this variety can successfully compete with varieties of similar ripeness groups.

Considering the spread of disease, we determined the systematic position of the pathogen, the intensity of the plants damage, and the time at which the disease began (according to phenological and calendar indicators). Observations were made at stationary sites during the plant growing season (at least every 10 days). They were used to identify the time of disease occurrence. As a result, the dynamics of the disease's development and the timing of its initial manifestations were defined. The route technique was used to account for affected plants along the diagonals of the field by looking at 10 plants in 10 areas. Two parameters were used to measure the phytopathological status of the crops: prevalence and degree or intensity of disease development [14].

Prevalence calculation formula:

$$P = \frac{n}{N} * 100,$$

n – number of affected plants (organs) involved in the samples, pcs;

N – total number (diseased and healthy) plants (organs) involved in the samples, pcs.

Disease progression (R) calculation formula:

$$R = \frac{\Sigma(n*b)}{\Sigma n},$$

Σ(nb) – sum of the products of affected plants multiplied by the degree of damage;

Σn – total number of damaged plants or similar organs in the samples, pcs.

The severity of the damage was determined by conditional grading [15].

The severity of disease development was expressed in percentages. We used the formula to convert the score to a percentage:

$$R = \left[\frac{\Sigma(n*b)}{A*\Sigma n}\right] * 100,$$

Σ(nb) – sum of the products of affected plants multiplied by the disease progression score;

Σn – total number of damaged plants or similar organs in the samples, pcs;

A – the highest score on the chart.

The calculation formula for the biological effectiveness of fungicides:

$$C = \left[\frac{(Y-y)}{y}\right] * 100,$$

У – rate of disease progression (control);

y – indicator of disease progression in the treated area.

Laboratory tests were performed in accordance with generally accepted State Standards and methods: state of crops and crop productivity according to the phenological stages of plant development; nature of the seeds according to State Standard PO42-80; yield was recalculated for standard (14%) moisture and 100% purity; crop structure – with the method of individual analysis of plants in a sheaf. Plant sampling was carried out on the days of counting. The analysis was conducted with the help of special equipment at the Biological Research Laboratory of Toraighyrov University. The mass of the roots and plants' underground parts was determined by using an analytical balance. Mathematical processing was conducted according to B.A. Dospekhov [16]. Variance and correlation analyses were performed on an IBMPC using the Excel program.

Results and Discussion

The following climatic conditions characterized the growing season of 2022. The temperature regime in May 2022 was quite mild. The average monthly temperature during the day was 17.5°C, which is 4.3°C higher than the long-term average temperature. The first and third 10 days of the month were marked by relative temperature stability, while the second decade was defined by temperature indicator variations. The lack of rainfall during the month was remarkable; the average amount of rainfall in May – 12 mm. The relative humidity (RH) was about 38%.

June was characterized by a gradual temperature rise. The first and second 10 days of June are marked by temperature reductions, although the average temperature for the whole month was almost 18.5°C. The temperature indicators were relatively stable in the third decade. The average June rainfall increased by up to 30 mm, causing the RH to rise by 50%.

The average monthly temperature in July was 21.5°C, which formed a moderate temperature regime that was 0.8°C higher than the long-term average. The monthly rainfall indicators showed uneven fluctuations up to 33 mm (39% less than normal) and relative humidity of about 55%. August was characterized by an absence of significant temperature variations: plus 20°C (average temperature) and a RH of 61%. Over the previous months, precipitation indicators increased by up to 52.1 mm (Table 1).

Table 1

Meteorological conditions (2022 growing season)

Month	Average temperature, ºC		
	Long-time average	2022	Deviation
May	13.2	175	+4.3
June	19.7	18.5	-12
July	20.7	22.5	+08
August	17.8	200	+22
Month	Precipitation, mm		
	Long-time average	2022	Deviation
May	24.4	12.0	-124
June	39.3	30.0	-9.3
July	54.0	33.0	-210
August	37.4	52.1	+14.7

The growing season of 2022 was characterized by a variety of weather conditions, some of which resulted in a negative impact on plant development and growth. A prolonged moisture deficit affected air temperatures, resulting in indicators that were mostly above long-term average values. The climate created favorable conditions for the development of many fungal diseases and their significant manifestation in spring wheat crops. Plants were affected by air and soil humidity, daytime temperatures, and fungal diseases.

Spring wheat was infected with powdery mildew (*Erysiphe graminis*), leaf brown rust (*Puccinia triticina*), and septoria leaf blotch (*Septoria sp.).* Powdery mildew intensity of manifestation was around 30%, rust intensity – 15%, and septoria leaf blotch intensity – 25% prior to the use of fungicides (during the stage of flag leaf emergence). The intensity of disease manifestation was considerably reduced in 10 days after fungicide application: powdery mildew by 75.1-90.1%, rust by 55.2-61.7%, and septoria leaf blotch by 35.1-48.6%. At the same time, Rex Duo fungicide was the most effective against the disease complex. After 20 days, Rex Duo completely suppressed powdery mildew, reduced leaf rust manifestation by 78.7% and septoria leaf blotch by 71.4%. By this time, the intensity of powdery mildew manifestation had dropped to

17.0% due to the action of abiotic factors (untreated region), but the same indicators of leaf rust and septoria leaf blotch had reached their maximum values (44,1% and 89.4%) (Table 2, Fig. 1-2).

Table 2

Biological efficiency of fungicides (flag leaf emergence)

Option	Biological efficiency against disease, %					
	Powdery mildew		Brown rust		Septoria leaf blotch	
	10 days	20 days	10 days	20 days	10 days	20 days
Kolosal Pro, 0.6 L/ha	75.1	91.1	55.2	67.2	35.1	61.6
Rex Duo, 0.5 L/ha	90.1	100.0	61.7	78.7	48.6	71.4
Varro, CS, 0.25 L/ha	85.4	98.8	58.3	70.0	44.4	68.2
Control	27.5	17.0	17.7	44.1	28.5	89.4
$LSD_{0,5}$	3.2	4.9	4.0	2.7	5.4	2.8

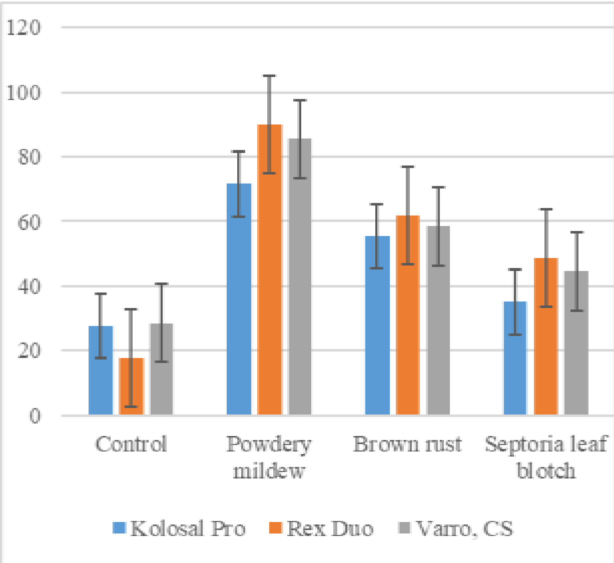

Figure 1. Biological efficiency of fungicide application after 10 days

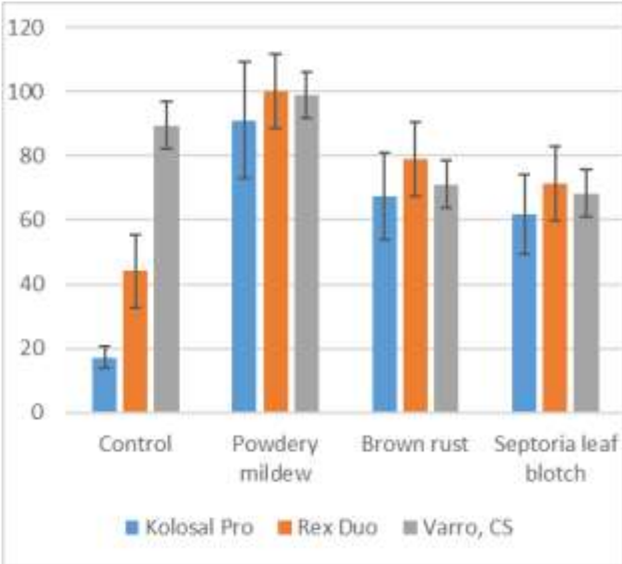

Figure 2. Biological efficiency of fungicide application after 20 days

Fungicides used during the growing season to control fungal diseases of spring wheat contribute to an increase in plant growth, the number of productive stems, ear height, grain number per ear, weight of 1000 grains, and the crop's biological yield (Table 3).

Table 3

Spring wheat indicators as a result of fungicide treatment (flag leaf emergence (37-39)

Option	Indicators					
	Productive stems, pcs/m^2	Plant height, cm	Grain number per ear, pcs	Weight of grains per ear, g	Weight of 1000 grains, g	Biological yield, centner/ha
Kolosal Pro, 0.6 L/ha	393	97.0	25.2	0.932	36.6	36.5
Rex Duo, 0.5 L/ha	394	98.3	27.8	1.092	39.5	42.8
Varro, CS, 0.25 L/ha	391	98.3	25.8	0.985	38.1	38.5
Control	392	95.3	25.1	0.883	35.0	34.6
$LSD_{0,5}$	4.9	2.1	1.6	0.13	1.2	1.3

The use of foliar dressings with Ammonium nitrate N_{34} and Rex Duo fungicide significantly improved the condition of spring wheat plants. As a result, the number of productive stems, height of plants, grain number per ear, and weight of 1000 grains have increased. These two dressings are especially effective in the tillering and heading stages. If the biological yield in the variant without fertilizers and fungicide was 38.9 centers/ha and 43.4 centers/ha in the variant with only fungicide, then a single dressing with ammonium nitrate (tillering stage) followed by a fungicide (flag leaf stage) increased the indicator to 52.7 centers/ha, while two dressings (tillering and heading stages) allowed for the maximum biological yield of 60.9 centers/ha (Table 4).

Table 4

Some indicators of spring wheat plants as a result of fungicide application (Nitrogen fertilizers background)

Option	Indicators					
	Productive stems, pcs/m^2	Plant height, cm	Grain number per ear, pcs	Weight of grains per ear, g	Weight of 1000 grains, g	Biological yield, centner/ha
Ammonium nitrate N_{34} (tillering stage) + Rex Duo 0.5 l/ha (flag leaf stage)	413	107.4	29.1	1.275	44.1	52.7
Ammonium nitrate N_{34} (tillering stage) + N_{34} + Rex Duo 0.5 l/ha (ending of stem elongation stage) + N_{34} (heading stage)	421	112.8	31.2	1.448	46.8	60.9
Rex Duo 0.5 l/ha (ending of stem elongation stage)	389	104.2	27.8	1.115	40.1	43.4
Control	390	99.1	26.8	0.997	36.9	38.9
$LSD_{0,5}$	6.5	4.9	2.2	0.22	2.1	2.9

The Rex Duo fungicide treatment (at a rate of 0.5 L/ha) led to a reduction in powdery mildew prevalence. As a result, on the 12th day, plant damage dropped from 100% to 18-20% and the severity of manifestation decreased from 45 to 5%. In view of the degree of powdery mildew occurrence, the drug's biological efficacy reached 89% (Table 5).

On the 22nd day, the powdery mildew prevalence decreased to 3-5% (100% for the control) and the severity of manifestation dropped from 60% (control) to 3% (treated plants). The biological effectiveness after treatment against powdery mildew was 92-95%.

Table 5

Some indicators of spring wheat plants as a result of fungicide application (Nitrogen fertilizers and growth regulator Binoram background)

Disease manifestation	Options								
	Rex Duo 0.5 L/ha + Binoram			Rex Duo 0.5 L/ha			Control		
	Before treatment	After 12 days	After 22 days	Before treatment	After 12 days	After 22 days	Before treatment	After 12 days	After 22 days
Powdery mildew									
Disease prevalence, %	100	18	4	100	20	5	100	100	100
Degree of development, %	30	5	3	30	5	3	30	45	60
Biological efficiency, %	-	89	95	-	88	92	-	-	-

Brown rust									
Disease prevalence, %	50	13	12	60	14	13	50	60	70
Degree of development, %	15	10	8	15	10	8	15	25	45
Biological efficiency, %	-	64	84	-	60	80	-	-	-
Septoria leaf blotch									
Disease prevalence, %	45	28	20	45	30	23	45	60	90
Degree of development, %	25	20	15	25	20	15	25	35	50
Biological efficiency, %	-	45	60	-	40	50	-	-	-

The drug's fungicidal activity on spring wheat was observed to be moderate in respect to leaf rust. After 12 days, the prevalence in the treated variations was 13-14%, compared to 60% in the control, and the degree of disease manifestation was 10%, compared to 25% in the control. According to the level of development, biological efficiency for this time period was 60-64%. After 22 days, the prevalence of brown rust in the control plot climbed to 70%, whereas it was substantially lower in the treated variations – up to 12-13%. After 22 days, the degree of disease development in the control area reached 45%, while in the treated variants it was 8%. In 2022, the biological efficacy of Rex Duo against spring wheat brown rust was 80-84% (after 22 days).

The drug's fungicidal effect on spring wheat was less pronounced with regard to septoria leaf blotch. After 12 days, the prevalence in the treated variations was 28-30%, compared to 60% in the control, and the degree of disease manifestation was 20%, compared to 35% in the control. According to the level of development, biological efficiency for this time period was 40-45%. After 22 days, the prevalence of septoria leaf blotch in the control plot increased to 90%, whereas it was substantially lower in the treated variations – up to 20-23%. After 22 days, the degree of disease development in the control area reached 60%, while in the treated variants it was 15%. In 2022, the biological efficacy of Rex Duo against spring wheat septoria leaf blotch was 50-60% (after 22 days).

The efficacy of Binoram was marginally improved by additional application to growing plants.

Conclusion

The adverse effect of fungal infections on cereal plants rose in the 2022 growing season. It was discovered that if modern fungicides were not applied, disease spread, intensity of manifestation, and rate of development reached maximum levels.

The fungicides (tested under stressful conditions produced by phytopathogens and unfavorable meteorological conditions) enhanced the growth of spring wheat plants and positively influenced yield morphometric parameters, productivity, and grain quality parameters.

The research demonstrated an inhibiting effect of the fungicides (Varro, Rex Duo, and Kolosal Pro) on pathogenic microorganisms. This had an effect on grain quality and yield characteristics. The most effective agent for controlling diseases of spring wheat in the Pavlodar region is the fungicide named Rex Duo.

The use of fungicidal treatments in combination with fertilizers and plant growth regulators increased yield structure indicators, which resulted in an even greater impact on yield and quality indexes. Thus, it was discovered that the use of fertilizers and growth stimulants to crops can be combined with the application of fungicides.

Acknowledgements

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Р.М. Уалиева

Препараттардың фунгицидтік белсенділігін және олардың жаздық бидайдың патогенді микромицеттеріне әсерін салыстырмалы бағалау

2022 жылдың вегетациялық маусымы ауа райының әртүрлі жағдайларымен ерекшеленді және жаздық бидайдың дамуының белгілі бір кезеңдерінде дақылдың өсуі мен даму көрсеткіштеріне қолайсыз болды. Өсімдіктер күндізгі температураға, ауа ылғалдылығына және жер жамылғысына, саңырауқұлақ ауруларының деструктивті әсеріне байланысты күйзеліске ұшырады. Жаздық бидайда ақұнтақ (Erysiphe graminis), қоңыр тат (Puccinia triticina) және септориоз (Septoria sp.) сияқты аурулар дамыды. Өнімділікті арттыру және астық сапасын жақсарту үшін негізгі тыңайтқыш, тамырдан тыс үстеп қоректендіргіш, дақылға қатысты реттеуші қасиеттері бар заттар қолданылады. Жаздық бидай ауруларын бақылаудың тиімді саңырауқұлақжойғылары — Варро, Рекс Дуо, Колосал Про. Зерттеу нәтижесінде осы саңырауқұлақжойғыларының жаздық бидайдың негізгі қоздырғыштарын басуға және соның салдарынан астықтың өнімділігі мен сапасына әсері анықталды. Қоздырғыштар мен ауа райының қолайсыздығынан туындаған күйзеліс жағдайында саңырауқұлақжойғылар жаздық бидай өсімдіктерінің өсуіне, дақыл құрылымының көрсеткіштеріне, өнімділік және астық сапасының көрсеткіштеріне оң әсер етті. Жаздық бидай ауруларын бақылаудың ең тиімді заты — Рекс Дуо фунгициді. Тыңайтқыштар мен өсімдіктердің өсуін реттегіштерді қолдана отырып, фунгицидтік препараттарды біріктіргенде жаздық бидайдың егін жинау құрылымының көрсеткіштері жақсарғаны анықталды, бұл дақылдың өнімділігі мен астық сапасының артуына әсер етті. Тыңайтқыштар мен өсу стимуляторларын пайдалану дақылдарды фунгицидтік препараттармен өңдеумен үйлесімді екендігі айқындалды.

Кілт сөздер: жаздық бидай, фитопатогендер, микромицеттер, фунгицидтер, тыңайтқыштар, өсу стимуляторы, ақұнтақ, қоңыр тат, септориоз.

Р.М. Уалиева

Сравнительная оценка фунгицидной активности препаратов и их воздействие на патогенные микромицеты яровой пшеницы

Вегетационный сезон 2022 г. отличался различными условиями погоды, и в определенные фазы развития яровой пшеницы был неблагоприятен для показателей роста и развития культуры. Растения испытывали стресс по отношению к дневным температурам, влажности воздуха и почвенного покрова, деструктивному влиянию грибных болезней. На яровой пшенице получили развитие мучнистая роса (Erysiphe graminis), листовая бурая ржавчина (Puccinia triticina) и септориоз (Septoria sp.). С целью повышения урожайности культуры и улучшения качества зерна используют удобрения, внекорневые подкормки, также вещества, которые обладают регулятивными свойствами по отношению к культуре. Одними из эффективных средств по контролю болезней яровой пшеницы являются фунгициды Варро, Рекс Дуо, Колосаль Про. В результате проведенного исследования установлено влияние указанных выше фунгицидов на подавление основных фитопатогенов яровой пшеницы, и, как следствие, на урожайность, и качество зерна. В стрессовых условиях, вызванных фитопатогенами и неблагоприятными условиями погоды, исследуемые фунгициды способствовали росту растений яровой пшеницы, положительно влияли на морфометрические показатели урожая, урожайность культуры и показатели качества зерна. Наиболее эффективное действие при борьбе с болезнями яровой пшеницы, такими как мучнистая роса, бурая ржавчина, септориоз, оказывает фунгицид Рекс Дуо. Установлено, что в сочетании фунгицидных препаратов с применением удобрений и регуляторов роста растений улучшились показатели структуры урожая яровой пшеницы, что сказалось на повышении урожайности и качества зерна культуры. Выявлено, что внесение удобрений и стимуляторов роста совместимо с обработкой посевов фунгицидными препаратами.

Ключевые слова: яровая пшеница, фитопатогены, микромицеты, фунгициды, удобрения, стимулятор роста, мучнистая роса, бурая ржавчина, септориоз.

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