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RESISTANCE TO FUNGAL DISEASES IN PLANT FORMS IS ACHIEVED BY CROSSING VARIETIES OF SPRING SOFT WHEAT WITH VARIETIES OF SPRING TRITICALE AND WILD WHEAT SPECIES.

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ABSTRACT

Fungal diseases cause significant damage to the yield of spring soft wheat. Currently, the main method for combating these diseases in agricultural production is treating seeds with fungicides. However, breeding resistant varieties is a more promising approach. This can be achieved by crossing varieties of spring triticale with spring soft wheat to develop resistance to these pathogens. The search and selection of suitable initial forms can be conducted in vitro using special nutrient media to identify resistant varieties of spring soft wheat, spring triticale, and their hybrid forms. We have studied 22 seed samples, including various varieties of spring soft wheat, spring triticale, hybrid forms from crossing these species, and wild wheat species. We assessed their resistance to fungal pathogens, specifically *Alternaria* spp. and *Fusarium* spp.

Key words: *pathogenic fungi, Alternaria spp., Fusarium spp., Mucor spp., spring soft wheat, spring triticale, wild wheat species, hybrid plant forms, resistance to fungal diseases.*

1. INTRODUCTION

A significant portion of agricultural enterprises worldwide, including in Kazakhstan, focuses on growing wheat and producing various products derived from it [1]. Wheat production is crucial for ensuring global food security. However, several factors, both biological and non-biological, can significantly impact the yield of this crop. These factors include environmental conditions, climate change, herbivorous insects that damage plants, and fungal and viral diseases [2].

One of the most significant challenges in wheat cultivation is the prevalence of diseases caused by various pathogenic fungi. These diseases are widespread in nearly all regions where grain crops are grown [3]. The incidence of such diseases is influenced by factors including the type of pathogen, weather conditions, humidity, and the susceptibility of wheat varieties. It is important to note that disease outbreaks can vary widely depending on the season and cultivation zone. For instance, some types of rust have the potential to destroy up to 100 percent of certain wheat varieties, posing a severe threat to global agriculture. According to the Food and Agriculture Organization of the United Nations (FAO), annual global wheat crop losses due to diseases and pests increased from 52.2 million tons in 1986-1990 to 70 million tons in 1998-2005 [4].

Fungal diseases significantly reduce crop yields in grain crops and have been identified in nearly all countries and regions around the world. Scientists have documented approximately 50 species of fungi that can partially or completely destroy crop root systems. Among grain crops, complex fungi of the genus *Fusarium* are particularly prevalent [5]. Common pests in wheat crops include *Bipolaris sorokiniana*, various species of *Alternaria*, *Fusarium*, and *Penicillium*. These fungi are major causative agents of root rot and diseases such as black ear disease [6]. In northern Kazakhstan, as well as in the western and eastern regions of the republic, the most prevalent and harmful diseases include helminthosporium-fusarium root rot, brown rust, stem rust, septoria leaf spot, and yellow spot of wheat. These diseases are transmitted through seeds, persist in post-harvest residues in the soil, and spread via airborne droplets or transmission [7].

Each year, grain crops are affected by root rot, leaf septoria, powdery mildew, pyrenophorosis, and brown rust, which lead to reduced yields and deteriorated quality of plant products. This situation necessitates protective measures throughout the growing season [8]. Fungicides are widely used globally to combat root and leaf-stem infections. However, selective breeding can also make a significant contribution to the fight against fungal diseases in cereal crops. Therefore, developing source material for breeding spring soft wheat varieties resistant to fungal diseases is crucial for preventing crop losses.

A relatively large number of fungal-resistant plant forms can be found among the biological diversity of wild wheat species and crops such as spring or winter triticale. Triticale (×Triticosecale Wittmack) is an intergeneric hybrid obtained by crossing tetraploid wheat (Triticum turgidum ssp. durum, genome AABB) with diploid rye (Secale cereale L., genome RR), resulting in a hexaploid genetic structure (AABBRR) with $2n = 6x = 42$ chromosomes [9]. Modern commercial spring triticale varieties are nearly completely resistant to biotrophic pathogens, including powdery mildew, leaf rust, stripe rust, and stem rust.

The aim of our work was to study the sensitivity of hybrid forms of plants obtained on the basis of intergeneric crossings of different varieties of spring soft wheat, spring triticale and wild wheat species to such fungal pathogens as *Alternaria* spp., *Fusarium* spp., *Mucor* spp.

2. MATERIALS AND METHODS

The seed material fully complied with the requirements of GOST 12044-93, «Seeds of Agricultural Crops: Methods for Determining Disease Contamination.»

The seeds of hybrid plant forms, spring soft wheat varieties, and spring triticale were first washed under running water for 1-2 hours. They were then disinfected with 96% alcohol for 1-2 minutes. After disinfection, the seeds were rinsed with sterile water and dried between layers of sterile filter paper. Ten seeds were placed in each Petri dish and incubated in a thermostat at 25-27 °C for germination, a process that typically lasted from 7 to 10 days. To examine the seeds for the presence of pathogens, a small portion of the growing colony was observed in a drop of water under a Zeiss AxioScope A1 microscope. The study was conducted on 22 seed samples, including different varieties of spring soft wheat, spring triticale, various hybrid forms from crossing spring soft wheat with spring triticale, and wild wheat species (Table 1).

Statistical analysis of the results was conducted using standard methods in Microsoft Excel.

Table 1 – Varieties and Hybrid Forms of Spring Soft Wheat and Spring Triticale Used in Studies on Resistance to Fungal Diseases.

#	Hybrids / Varieties	Characteristics
1	Lider 80*Dauren	Soft spring wheat × Spring triticale
2	KS 115/09-1* Dauren	Soft spring wheat × Spring triticale
3	Uralsibirskaya 2* Dauren	Soft spring wheat × Spring triticale
4	Rossika*Chelyaba Rannya	Spring triticale × Soft spring wheat
5	Rossika * Chelyaba Rannya	Spring triticale × Soft spring wheat
6	Akmola 2* Rossika	Soft spring wheat × Spring triticale
7	Svetlanka* Rossika	Spring wheat × Spring triticale
8	Lutescens №97*XN 08	Spring wheat × Spring wheat
9	Spelta*Lyt 1300	Wheat × Soft spring wheat
10	Spelta*Lyt 1300	Wheat × Soft spring wheat
11	Amigo*Akmola	Spring triticale × Soft spring wheat
12	Norman*Astana	Spring triticale × Soft spring wheat
13	Kamut*Pirotrics	Wheat × Soft spring wheat
14	Astana*Persicum	Soft spring wheat × wheat
15	Polba*Gganni	Wheat × Spring wheat
16	Amigo*Akmola	Spring triticale × Soft spring wheat
17	Astana	Soft spring wheat
18	Akmola 2	Soft spring wheat
19	Svetlanka	Spring wheat
20	Rossika	Spring triticale
21	Chelyaba Rannya	Soft spring wheat
22	Pirotrics 28	Spring wheat

3. Results

In the experiment, the pathogen identification process involved several stages, starting with pathogen inoculation on PDA nutrient medium. The crops were then incubated at 22-25°C for 3-15 days. The results of the primary sowing of hybrid crop seeds are illustrated in Figures 1-3. These results revealed several hybrids and varieties with varying degrees of resistance to fungal infections. Seven hybrids (Nos. 1, 2, 3, 4, 7, 10, 12) and one Astana variety (No. 17) exhibited no resistance to fungal infections (Figure 1).

Seven hybrids (Nos. 6, 8, 9, 11, 13, 14, 16, 18) and one variety, Akmola 2 (No. 18), demonstrated reduced resistance to fungal pathogens (Figure 2). Conversely, some of the studied material showed resistance to fungal pathogens, including three hybrids (Nos. 5, 15, 20) and three varieties (Nos. 19, 21, 22) (Figure 3).

Pure cultures were isolated from the primary culture to identify the pathogens based on their cultural and morphological characteristics. The culture process was continued until characteristic sporulation appeared. These sporulations were then subjected to macroscopic examination to determine the identity of the fungal cultures. This method ensures accurate pathogen identification, which is critical for precise diagnosis (Figure 4).

Figure 4 shows pure cultures of primary fungal pathogens infecting cereal crops isolated from hybrid cultivars: *Alternaria* spp., *Fusarium* spp., and *Mucor* spp.

Alternaria spp. (Figure 4A): Colonies initially appear salmon-pink or light gray, darkening to gray or olive over time. They are fluffy or woolly with a moderate growth rate. Micromorphology: Hyphae are septate and vary from light to dark brown. Conidiophores are brown, straight or slightly

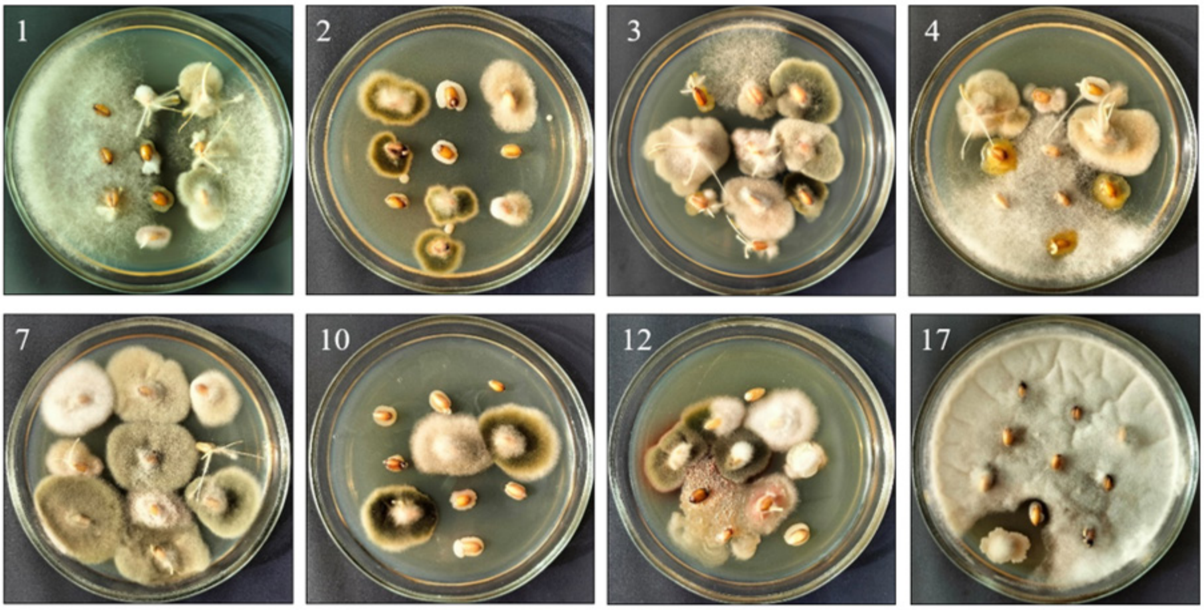

Figure 1 – Microbiological Analysis of Hybrids and Varieties with Low Resistance to Fungal Pathogens.

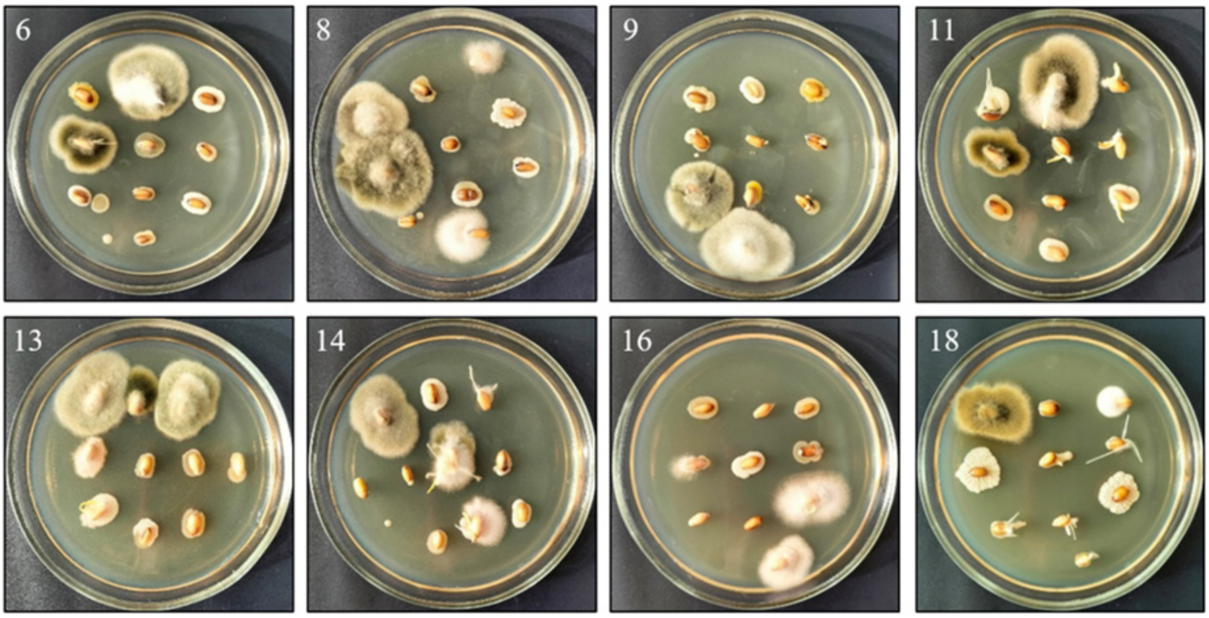

Figure 2 – Microbiological Analysis of Hybrids and Varieties Showing Reduced Resistance to Fungal Pathogens.

curved, up to 50 µm long, with 1-3 septa. Conidia are golden brown, forming long, branching chains of 10 or more, with variable shapes (ovoid, inversely club-shaped, inversely pyriform) and an apical beak. They have 3-8 transverse and 1-2 longitudinal septa [10, p. 22].

Fusarium spp. (Figure 4B): Colonies are flocculent (cotton wool-like) with white aerial mycelium that has a slightly violet tint, and the reverse side varies from colorless to dark violet, with rapid growth. Micromorphology: Hyphae are septate and have a violet tint. Conidiophores are short. Macroconidia are numerous, 23–54 × 3–4.5 µm in size, slightly sickle-shaped, thin-walled, and have 3–5 septa [10, p. 196].

Mucor spp. (Figure 4C): Colonies are gray on the surface and vary from gray to yellow-gray on the reverse side. The mycelium has a hairy texture and grows rapidly, often covering the entire Petri dish in a few days. Micromorphology: Hyphae are broad and sparsely septate. Sporangiophores are short (<18 µm), tapering toward the apex and septate. Sporangia are spherical (20-80 µm) and gray-black. Sporangiospores (4-8 µm) are subspherical or elliptical [10, p. 266].

4. DISCUSSION

Alternaria spp. are responsible for Alternaria infection, which affects both ears and grains. This infection causes grains to become discolored, turning dirty gray, and leads to shrinkage [11]. The extent of damage from *Alternaria* depends on climatic conditions during grain ripening and storage practices. Improper storage can lead to mold development and reduced crop quality [12]. *Alternaria* is especially prevalent in years with high temperatures (above 24°C) and high humidity during wheat anthesis and the milky stage of grain development. Seeds infected with *Alternaria* are physiologically underdeveloped, exhibiting low germination energy and viability. Plants grown from such seeds show stunted growth and

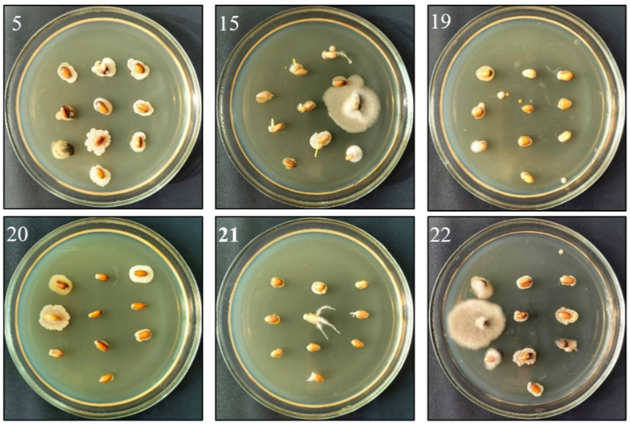

Figure 4 – Microbiological Analysis of Hybrids and Varieties Exhibiting Resistance to Fungal Pathogens.

development, resulting in reduced yields [13]. Additionally, many *Alternaria* species produce toxins harmful to humans and animals, adversely affecting seeds and seedlings, which impacts plant growth, development, and productivity [14].

Fusarium spp. are known to cause Fusarium wilt, leading to significant losses in both yield and grain quality. Infection with *Fusarium* fungi reduces germination vigor and seed viability. Some *Fusarium* species produce mycotoxins such as deoxynivalenol (DON), T-2 and HT-2 toxins, zearalenone, and nivalenol, which contaminate grain and render it unsuitable for food and feed purposes [15].

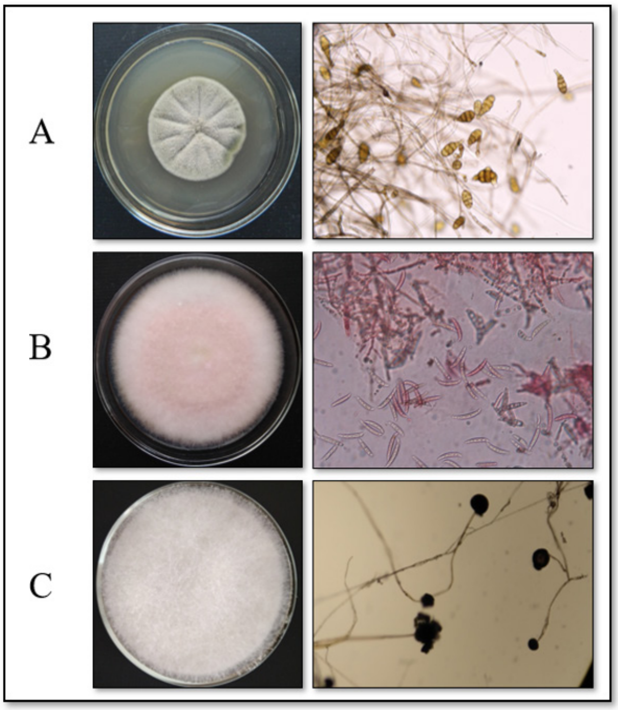

Figure 4 – Pure Cultures of Fungal Infections and Their Microscopy: A - *Alternaria* spp., B - *Fusarium* spp., C - *Mucor* spp.

Mucor spp., saprophytic fungi, often result from improper seed storage conditions. These fungi can spoil seeds under high humidity, making them unsuitable for sowing or animal feed [16]. Additionally, some saprophytic organisms that develop on grains under high humidity conditions can produce toxic substances that further degrade seed quality and safety [17].

Fungal diseases can cause significant damage to spring soft wheat and other cereal crops. Currently, the primary method for protecting spring soft wheat seeds from fungal diseases is seed treatment with fungicides, which is a mandatory and crucial practice in agricultural production. However, many researchers believe that the most promising approach to combating fungal diseases is the development and selection of resistant varieties.

Breeding institutions in Northern Kazakhstan have not yet addressed this issue comprehensively. In our studies, several hybrids exhibited low resistance to fungal diseases: **Lider 80 × Dauren** (Soft Spring Wheat × Spring Triticale), **KS 115/09-1 × Dauren** (Soft Spring Wheat × Spring Triticale), **Uralsibirskaya 2 × Dauren** (Soft Spring Wheat × Spring Triticale), **Rossika × Chelyaba Rannya** (Spring Triticale × Soft Spring Wheat), **Svetlanka × Rossika Spring** (Wheat × Spring Triticale), **Spelta × Lyt 1300** (Wheat × Soft Spring Wheat), **Norman × Astana** (Spring Triticale × Soft Spring Wheat).

Hybrids showing average resistance to fungal diseases included: **Akmola 2 × Rossika** (Soft Spring Wheat × Spring Triticale), **Lutescens №97 × XN 08** (Spring Wheat × Spring Wheat), **Spelta × Lyt 1300** (Wheat × Soft Spring Wheat), **Amigo × Akmola** (Spring Triticale × Soft Spring Wheat), **Kamut × Pirotrics** (Wheat × Soft Spring Wheat), **Astana × Persicum** (Soft Spring Wheat × Wheat).

Varieties and hybrids with demonstrated resistance to fungal diseases were: **Rossika** (Spring Triticale), **Svetlanka** (Spring Wheat), **Pirotrics 28** (Spring Wheat), **Chelyaba Rannya** (Soft Spring Wheat), **Rossika × Chelyaba Rannya** (Spring Triticale × Soft Spring Wheat), **Polba × Gganni** (Wheat × Spring Wheat).

This material is of great interest for use in the selection process of spring soft wheat, aiming to create varieties resistant to fungal diseases.

CONCLUSION

Fungal diseases significantly impact the productivity of spring soft wheat. Currently, fungicides are a primary method for protecting spring soft wheat varieties from these diseases. However, a promising approach to combating fungal diseases is the development of resistant varieties. To create spring soft wheat varieties resistant to fungal diseases, initial material for selection can include varieties of spring triticale and spring soft wheat that have shown resistance to these pathogens. The search for such initial forms can be conducted in vitro using specialized nutrient media to identify resistance to the specific pathogens.

CONFLICT OF INTEREST

There are no conflicts of interest to declare.

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УСТОЙЧИВОСТЬ К ГРИБНЫМ ЗАБОЛЕВАНИЯМ ФОРМ РАСТЕНИЙ, СОЗДАННЫХ НА ОСНОВЕ СКРЕЩИВАНИЙ СОРТОВ ЯРОВОЙ МЯГКОЙ ПШЕНИЦЫ С СОРТАМИ ЯРОВОГО ТРИТИКАЛЕ И ДИКИМИ ВИДАМИ ПШЕНИЦЫ

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АБСТРАКТ

Грибные заболевания наносят ощутимый вред урожаю яровой мягкой пшеницы. В настоящее время в сельскохозяйственном производстве основным методом борьбы с данным видом заболевания является протравливания семян сортов данной культуры фунгицидами. Однако наиболее перспективным методом борьбы с грибными заболеваниями является выведение устойчивых сортов. Создание таких сортов возможно на основе использования в скрещиваниях сортов ярового тритикале и сортов яровой мягкой пшеницы к данному виду патогена. Поиск и отбор таких исходных форм для селекции можно проводить на специальных питательных средах in vitro путем идентификации сортов яровой мягкой пшеницы и ярового тритикале, а также гибридных форм между данными культурами на данный вид патогена. Нами проедены исследования 22 образцов семенного материала, представленного различными сортами яровой мягкой пшеницы, ярового тритикале, различными гибридными формами растений, полученными от скрещивания сортов яровой мягкой пшеницы с сортами ярового тритикале и дикими видами пшеницы. Установлена степень устойчивости к грибным возбудителям *Alternaria* spp. и *Fusarium* spp.

Ключевые слова: патогенные грибы, *Alternaria* spp., *Fusarium* spp., *Micor* spp., яровая мягкая пшеница, яровое тритикале, дикие виды пшениц, гибридные формы растений, устойчивость к грибным заболеваниям.

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ЖАЗДЫҚ ЖҰМСАҚ БИДАЙ СОРТТАРЫН ЖАЗДЫҚ ТРИТИКАЛЕ СОРТТАРЫМЕН ЖӘНЕ ЖАБАЙЫ БИДАЙ ТҮРЛЕРІМЕН ШАҒЫЛЫСТЫРУ НЕГІЗІНДЕ ЖАСАЛҒАН ӨСІМДІК ФОРМАЛАРЫНЫҢ САҢЫРАУҚҰЛАҚ АУРУЛАРЫНА ТӨЗІМДІЛІГІ

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АҢДАПТА

Жаздық жұмсақ бидайдың өніміне саңырауқұлақ аурулары айтарлықтай зиян келтіреді. Қазіргі таңда ауылшаруашылық өндірісінде аурудың бұл түрімен күресудің негізгі әдісі осы дақылдың тұқымының сорттарын фунгицидтермен емдеу болып табылады. Алайда, саңырауқұлақ ауруларымен күресудің ең перспективті әдісі - төзімді сорттарды дамыту. Жаздық тритикале сорттары мен жаздық жұмсақ бидай сорттарын шағылыстыру арқылы осы патогеннің түріне төзімділікті қалыптастыруда пайдаланылады. Селекцияға арналған осындай бастапқы формаларды іздеу және іріктеуді жаздық жұмсақ бидай мен жаздық тритикале сорттарын, сондай-ақ осы дақылдар арасындағы гибридті формаларды патогеннің осы түріне сәйкестендіру арқылы in vitro арнайы қоректік орталарда жүргізуге болады. Біз жаздық жұмсақ бидайдың әртүрлі сорттары, жаздық тритикале, жаздық жұмсақ бидай сорттары мен бидайдың жабайы сорттарын шағылыструдан алынған өсімдіктердің әртүрлі гибридті формалары көрсетілген тұқымдық материалдың 22 үлгісін зерттедік. *Alternaria spp.* және *Fusarium spp.* саңырауқұлақ қоздырғыштарына төзімділік дәрежесі анықталды.

Түйінді сөздер: патогенді саңырауқұлақтар, *Alternaria* spp., *Fusarium* spp., *Mucor* spp., жаздық жұмсақ бидай, көктемгі тритикале, жабайы бидай түрлері, өсімдіктердің гибридті формалары, саңырауқұлақ ауруларына төзімділік.