

Review Article

Initial Diagnosis of Barley Rust Disease Based on Visual and Morphological Signs

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Abstract

Barley is among the widely distributed and commercially necessary cereals in the world. However, diseases triggered by different kinds of plant pathogens pose a serious challenge to barley production. Some of these diseases are the rusts that are caused by various fungi belonging to the Puccinia species. The main characteristic of the rust disease in barley is its wide distribution and the fact that it leads to crop losses. Early detection of the rust disease is important for its management and containment. The presented article examines the possibilities of initial diagnosis of rust disease in barley plants based on visual and morphological indicators. The morphological characteristics of the pathogen, the color, shape, and location of the blotches, and the symptoms observed on the leaf surface of barley samples infected with rust disease were analysed during the study. The findings suggest that visual and morphological indicators can be employed as an effective and practical method for the early detection of rust disease in initial diagnostics. This method enables the implementation of operational decisions in the field, thereby reducing crop losses.

Keywords: barley, rust disease, uredospores, initial diagnostics

1. Introduction

Barley is one of the most important grain crops cultivated by humans since ancient times (*Hordeum vulgare* L.). Nearly 9,000 years ago, barley was first cultivated in the Middle East and has since become a globally significant food and livestock agricultural crop. Barley's capacity to endure severe climatic conditions enables it to cultivate grains in both arid and cold regions. As a result, barley is the fourth most abundant crop in the world in terms of both production volume and cultivated area, following rice, maize, and wheat. In addition to its culinary applications, barley is essential for both animal husbandry and industry [1].

A number of significant factors are indicative of the agricultural importance of barley. Barley is initially highly adaptable to a wide range of soil types and climates. It is a dependable crop for global cultivation due to its ability to survive in both semi-arid and cold environments. Secondly, barley's short growing season results in a higher yield than other cereals. Barley's contribution to global food security is demonstrated by the fact that it is grown on millions of hectares across the world and yields hundreds of thousands of tonnes of crops annually.

There are numerous nutritional and commercial uses for barley. Animal feed, particularly for dairy animals like cows and sheep, uses a significant amount of the entire crop. It also provides raw materials for the brewing industry. In some regions, it is also used to a significant extent for human consumption [2]. Barley is high in protein, fiber, and vitamins and minerals, which increases its value both in terms of food and industry. These properties are also crucial in protecting animal health.

In terms of productivity, barley is determined by various factors. Genetic characteristics, cultivation conditions, soil type, and wet and dry environments directly affect yield indicators. Plant height, number of ears, number of grains per ear and 1000-grain weight of barley varieties are evaluated as the main components of productivity. For

example, varieties with dense heads and large grains have higher yield potential. In addition, soil and irrigation conditions also affect yield. Yields can be 20-30% higher in well-irrigated areas [3]. Modern agricultural research evaluates the agro-morphological characteristics of different genotypes to increase barley productivity. As a result of these studies, the identification of high-yielding varieties and their application in breeding programs creates conditions for a continuous increase in productivity. The scientific works prove the direct relation between the biomass and the vegetation index of some barley genotypes and productivity. This means that choosing the right genotypes plays an important role. In addition, one should consider that barley is an indispensable agricultural product in Azerbaijan. It is the main food resource for cattle and grows everywhere in Azerbaijan. Some varieties of barley are grown in saline and low-fertility soils. Thus, the adaptability to many types of ecology has been proven by the studies. Modern breeding methods enable people to preserve and use the genetic resources of barley effectively in order to ensure productivity. The main purpose of developing barley genotypes is to raise productivity and secure food safety. Healthy soils and good cultivation practices are not the only reasons why this agricultural product is so productive. The good condition of plants plays an equally important role as well. Diseases affecting the leaves, stems, and grains may affect the plant negatively. They can influence photosynthesis and nutrient distribution. For this reason, it is necessary to establish appropriate management strategies and detect illnesses among barley fields at the right time in order to ensure sustainability in yield.

One of the many illnesses affecting agricultural areas is called barley rust (*Puccinia hordei* or other types of *Puccinia*). This disease leads to huge losses and is typical for the natural environment as well as for agricultural lands. Spots on the leaves of barley plants look like rust color and are connected with yellow and brown stains on leaves caused by this disease [4]. Such signs lead to a decrease in photosynthesis, energy accumulation, and grain growth. In conclusion, ensuring the productivity of barley plants involves managing diseases, as well as soil and fertilizing conditions. It means that specialists should conduct thorough research about symptoms, ways of infection spread, and prevention of this disease in order to avoid crop losses.

As it was already noted, the sustainability of agrarian significance depends on the capacity of growing this type of crop productively. Nevertheless, various stressors related to plant biology can limit the capacity of growing barley. Among these diseases is a rust, a condition that affects physiological processes within the plant while it is in the vegetative stage and leads to low productivity. Analyzing the biological and physical properties of the pathogen scientifically, as well as symptoms and the mechanisms of transmitting the disease, it is possible to better understand what triggers the decrease in productivity. At the same time, identifying rust disease accurately will be extremely useful for designing ways to overcome this problem.

Barley (*Hordeum vulgare* L.) rust is mainly caused by fungal pathogens and is considered one of the most widespread phytopathological problems in barley production worldwide, causing yield reductions. The causative agents of rust disease are obligate parasitic fungi belonging to the Basidiomycota division, the Pucciniales order, and mainly the *Puccinia* genus. Since these pathogens can only grow in living plant tissue, they have the ability to spread rapidly and cause widespread infection in the field. The main fungal species that cause rust in barley differ somewhat in the symptoms they cause in the plant and the form of infection. The most common rust species include leaf rust, yellow rust, and, to a lesser extent, stem rust [5].

2. Leaf Rust Pathogen (*Puccinia hordei* G.H. Otth)

The main cause of barley leaf rust is the fungus *Puccinia hordei*. This pathogen develops mainly on the leaf surface and manifests itself in the relatively late stages of the growing season. After entering the leaf tissue, the fungus develops under the epidermis and produces uredospores. As a result, round or oval brown or orange rust pustules form on the leaves. *P. hordei* develops rapidly in conditions of high humidity and mild temperatures. The disease weakens the photosynthesis process and causes premature drying of the leaves, which leads to serious yield losses during the grain-filling stage. The physiological deterioration of the barley plant is typically observed alongside leaf rust, which can be clearly identified visually in field conditions.

3. Yellow Rust Pathogen (*Puccinia Striiformis* Westend f. sp. *hordei*)

Puccinia striiformis f. sp. *hordei* is suspected to be the cause of yellow rust disease, a pathogen that is particularly hazardous in humid and cold climates. The primary visual indicator of yellow rust is the presence of yellowish pustules that are arranged in parallel stripes on the leaf surface. This is one of the primary signs that differentiate yellow rust from other rust varieties. This pathogen has a more serious negative impact on barley plant development because it can become active in the early vegetative stage. In plants infected with yellow rust, a large part of the leaf surface loses its functional activity, resulting in a weakening of the overall development of the plant and a sharp decrease in yield. Since *P. striiformis* is highly adaptable, the emergence of new physiological races is also possible, which makes disease control difficult.

4. Stem Rust Pathogen (*Puccinia graminis* Pers f. sp. *tritici* Erikss. & Henning)

Although less common in barley, stem rust is also a potentially dangerous disease. The causative agent of this disease, *Puccinia graminis* f. sp. *tritici*, is mainly characteristic of wheat, but under certain conditions, it can also infect barley plants. Stem rust is observed as the formation of elongated, dark-colored rust spots on the plant stem, leaf sheaths, and sometimes the spikes. This pathogen weakens the mechanical resistance of the plant, causing stem breakage and plant dormancy. As a result, crop losses increase not only in terms of grain quality but also in terms of difficulties during harvesting.

5. General Biological Characteristics of Rust Pathogens

One common characteristic of the fungi that cause barley rust is that they have a complex development cycle. These pathogens produce different types of spores (uredospores, teliospores, and basidiospores) during their life cycles. In particular, uredospores play a key role in the rapid spread of the disease during the growing season. Rust has the potential to rapidly infect huge areas of cropland due to its ability to be transported over great distances by the wind.

6. Optimal Conditions for the Evolution of Rust Disease

The environmental factors and agrotechnical conditions are directly correlated with the spread and intensive development of rust disease in barley. Rust pathogens are obligate parasitic organisms, which means that their development is dependent upon the presence of susceptible plants and the presence of appropriate environmental conditions. Accordingly, the emergence and rapid spreading of rust disease frequently occur as a consequence of the simultaneous action of numerous factors [6].

7. Meteorological and Climatic Parameters

The optimal conditions required for the proliferation of rust are when there is moisture-laden air along with mild temperatures. This means dew drops formed on leaves, particularly after heavy rains or during the night period, form an excellent environment for the growth of fungal spores. For the germination of uredospores and their entry into the plant's tissue, the leaf must remain moist for some period. Moreover, rust disease also depends on temperature levels. In general, rust fungi operate within the range of 15 to 25 degrees Centigrade. Though yellow rust grows well in low temperatures, leaf rust might adjust well in warm conditions [7]. The ideal mix of humidity and warmth allows the disease to spread quickly over wide areas.

8. Physiological and Developmental Stage of the Plant

Barley plants' vulnerability to rust disease varies during the growing season. Between the tillering and heading periods, the disease is at its most active. Pathogens can more easily enter plant tissue during this time due to the broad leaf surface and high photosynthetic intensity. Rust is more likely to affect plants that are undernourished, agitated, or damaged by other diseases. The application of nitrogen fertilizers in excess results in an increase in vegetative growth, which in turn creates a favorable environment for rust pathogens by increasing the humidity of the microclimate.

9. Agricultural Technical Parameters

The proper or improper implementation of agrotechnical measures significantly influences the spread of rust disease. Densely planted areas weaken air circulation, and prolonged moisture on the leaf surface accelerates the development of fungal infections. At the same time, keeping diseased plant residues in the field allows pathogens to continue their activity in the next growing season. Long-term barley cultivation as a monoculture leads to an increase in sources of infection in the soil and the environment. Failure to apply a crop rotation system leads to the recurrence of rust disease every year and its manifestation at earlier stages.

10. Variety Characteristics and Genetic Susceptibility

The level of genetic resistance of barley varieties to rust disease directly affects the rate of disease development. Susceptible varieties can be massively infected in a short period of time under suitable climatic conditions. Resistant varieties, on the other hand, limit the development of pathogens to some extent, thereby slowing down the spread of the disease. However, the high variability of rust pathogens can infect even previously resistant varieties in some cases. This factor is one of the main reasons why rust disease remains a persistent phytosanitary problem.

11. External Sources of Infection and Routes of Spread

One of the significant factors affecting the development of rust disease is the mechanism of infection spread. Rust spores can be carried very long distances by the wind. Therefore, the disease can be transmitted not only within a field but also from neighboring crops. When suitable climatic conditions are created on a regional scale, rust disease can infect large areas in a short time [8]. As a result of the influence of the mentioned ecological and agrotechnical factors, rust disease is accompanied by characteristic visual and morphological changes in barley plants, which allow for initial diagnostics in field conditions.

12. Initial Diagnosis Based on Visual Signs of Rust Disease

Visual observations play a key role in the initial diagnosis of rust disease in the field. The characteristic external signs produced by the pathogens of the disease allow us to determine the presence of infection even without laboratory analysis. Correct assessment of visual symptoms is necessary in differentiating rust from other leaf spot diseases and in taking timely control measures.

13. Symptoms Observed on Leaves

The initial visual symptoms of rust disease are most often observed on the leaves of barley plants. In the early stages of the illness, the leaf surface develops tiny, yellowish or light orange dots. As they age, these patches enlarge and turn into brown, orange-brown, or yellow pustules. The pustules typically burst through the leaf tissue, emerging from the leaf epidermis. On the leaf surface, rust pustules can appear irregularly or in a specific pattern. Leaf rust spots are typically observed in dispersed patterns, while yellow rust pustules form parallel bands along the leaf veins. Usually, the pustules emerge from the leaf epidermis after rupturing through the leaf tissue. Rust pustules can show up randomly or in a particular pattern on the leaf surface. While yellow rust pustules form parallel bands along the leaf veins, leaf rust patches are usually found in scattered patterns [9]. This characteristic is thought to be essential for identifying different forms of rust in the field. As the disease progresses, the number of pustules increases, merging to cover a large part of the leaf surface. In the end, the photosynthesis process weakens, the leaves turn yellow prematurely, and they start to dry out. Severe infections sharply reduce the functional activity of the leaves, negatively impacting the overall development of the plant.

14. Signs on the Stem and Leaf Sheath

In the advanced stages of rust disease, the barley plant's stem and leaf sheaths also exhibit visual symptoms. These symptoms are especially pronounced during stem rust. Oblong, dark brown or reddish-brown rust spots appear on the surface of the stem and leaf sheaths. The appearance of these areas adversely affects the mechanical strength

of the tissue of the stem and leads to its epidermis cracking. Thus, the plant is more susceptible to the impact of outside factors. In cases of acute infection, the weakness in the stem leads to the falling of the plant falling to the ground; it is prone to lying on the soil surface. The transmission of nutrients by the plant is even more restricted because of rust indications on the leaf sheaths.

15. General Morphological State of the Plant

In the case of visual identification of rust disease, the overall morphology of the plant and the signs on the organs under observation are regarded as important indicators. Plants affected by rust disease possess low vegetative biomass compared to healthy plants. Barley plants exhibit early signs of ageing with severe infestations. Early leaf drying prevents the plant from properly absorbing nutrients. During the grain filling stage, this situation is very noticeable [10]. Because of this, the grains that form in the spikes are weak, tiny, and light in weight. In cases where the rust disease persists for a long time, the plants become sparse, and uneven development is observed in the field. These morphological changes are considered one of the main indicators that allow assessing the intensity of the disease and conducting initial diagnostics in field conditions.

16. Diagnostic Indicators Based on Morphological Features

In addition to visual observations, the study of the morphological characteristics of the pathogen is of particular importance in the accurate diagnosis of rust disease. Morphological diagnosis is mainly based on the examination of fungal spores under a microscope, and this method allows the differentiation of rust disease from other leaf spot or necrotic diseases. Although symptoms observed in the field provide preliminary information, morphological indicators play a significant role in determining the causative agent of the disease [11].

17. Morphological Characteristics of Uredospores

The most common spore type during the active spread of rust disease is uredospores. These spores are mainly formed within rust pustules that form on the leaf surface and play a key role in the spread of the disease during the growing season. Uredospores are usually oval, elliptical, or ovoid in shape under the microscope. Their color is yellow-brown or orange-brown. The surface of the uredospores is covered with small spiny protrusions, which is one of the characteristic morphological features of rust fungi. The relatively thin but flexible spore wall allows them to be easily dispersed by wind. These morphological features allow uredospores to be distinguished from spores of other phytopathogenic fungi.

18. Morphological Characteristics of Teliospores

In later stages of the disease, teliospores are formed in the rust pustules. Teliospores are thicker-walled and more durable than uredospores. These spores are usually dark brown or black in color and are characterized by their two-celled structure. The main function of teliospores is to ensure the survival of the pathogen in unfavorable conditions. Microscopic observation reveals that the tips of teliospores may become thickened, and the distinct visibility of the septum between cells enhances their diagnostic value. These features allow us to determine the stage of development of the rust disease and assess its phenological period.

19. Color and Location of Spore Mass

In morphological diagnosis, both the morphology of the spores and their colors, and even the mannerisms in which the spores appear on plants, are considered important criteria. Orange-brown in color and scattered on the leaves, spore masses of leaf rust appear. In yellow rust, spore masses appear in stripes on the leaf veins with a pale-yellow color. Spore masses of stem rust have dark colors, and long pustules can be observed on the leaves and sheaths of the stem. Morphological characteristics become highly valuable in distinguishing among rust species [12].

20. Additional Microscopic Diagnostic Parameters

The dimensions, wall thickness, and texture of the spores, along with the condition of the host tissue, are considered while making a diagnosis of rust pathogens. In the affected tissues, there is growth of hyphae between the cells and destruction of epidermal cells. This indicates that the parasite is parasitizing the plant tissues. When the two methods are used together, the accuracy of the diagnosis improves immensely. The rust disease can be accurately diagnosed, particularly when laboratory tests confirm the results found initially in the field.

21. Conclusion

According to the findings of the analysis, rust disease is a severe phytopathological problem that affects barley's (*Hordeum vulgare* L.) grain yield and quality. The disease-causing fungus of the genus *Puccinia* is extremely adaptive and can spread quickly in favorable ecological and agrotechnical settings. This element emphasizes how crucial it is to identify rust disease in the environment as soon as possible. The results of the study demonstrate the importance of visual indicators in the early detection of rust illness. By looking for the distinctive rust pustules on the leaves, stems, and leaf sheaths, as well as the development of striped or scattered patches on the leaf surface, the disease can be quickly detected in the field. In the meantime, the overall morphological state of the plant, which includes early yellowing, slow growth, and core shrink is used to determine the severity of the disease.

The study of morphological characteristics, particularly the microscopic characteristics of uredospores and teliospores, alongside visual symptoms, greatly enhances diagnostic precision. The disease can be differentiated from other leaf spot pathogens, and the specific pathogen can be determined based on the particle's shape, color, cell wall construction, and localization [13]. It can be concluded that the early detection of rust disease through visual and morphological symptoms renders its prevention highly important both scientifically and practically. This method reduces crop loss in barley cultivation, and at the same time increases the efficiency of plant disease prevention techniques. In future research, combining molecular techniques with diagnostic methods may help build more efficient control strategies against rust disease.

Author Contributions

The author conceived and designed the study, conducted the literature review, analyzed the data, and wrote the article. The author reviewed and approved the final version of the paper.

Conflict of Interest

The author declares no conflicts of interest.

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