POPULAR ARTICLE

Developing White Rust Resistance in Rapeseed-Mustard: A Modern Perspective

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Abstract:

Indian mustard *(Brassica juncea*) is a Rabi season crop primarily grown in the northern states of India. Its production is influenced by various biotic and abiotic stresses. Among these, white rust disease caused by the oomycete fungal pathogen *Albugo candida* is a significant threat to rapeseed-mustard cultivation. This disease leads to substantial yield losses, impacting the income of farmers. The article focuses on the symptoms, life cycle, management strategies, and improved breeding techniques for combating white rust disease. Emphasizing disease resistance, the study highlights the importance of developing resistant varieties through breeding, genetic engineering, and marker-assisted selection. This strategy aims to enhance crop yield and quality while minimizing the need for pesticides, thereby contributing to environmental preservation.

Introduction:

Indian mustard [*Brassica juncea* (L.) Czern and Coss)] is an important winter crop in India, typically grown from October to March. It is primarily cultivated in the northern and eastern parts of the country including the states of Rajasthan, Uttar Pradesh, Haryana, Punjab, Bihar, and West Bengal. India is one of the largest producers of mustard in the world with 6.69 mha area and 10.11 mt production during 2020-21, and the crop is an important source of income for many small farmers. Like all crops, Indian mustard is susceptible to various diseases that can reduce its yield and quality. Some of the important diseases of Indian mustard are white rust (caused by *Albugo candida*), stem rot (caused by *Sclerotinia sclerotiorum*), *Alternaria* leaf blight (caused by *Alternaria brassicae*), powdery mildew (caused by *Erysiphe cruciferarum*) and downy mildew(*Hyaloperonospora parasitica).* Among these diseases, white rust disease caused by a biotrophic oomycetous pathogen *A. candida* is one of the important diseases of rapeseed-mustard. It can cause 10-70% yield losses in India. White rust disease affects many plant species worldwide, including Indian mustard (*Brassica juncea*). In this article, the symptoms, life cycle, and management strategies of white rust disease in Indian mustard with particular focus on disease resistance have been discussed.

Classification:

Kingdom	: Chromista
Phylum	: Oomycota
Class	: Oomycetes
Subclass	: Albuginomycetidae
Order	: Albuginales
Family	: Albuginaceae
Genus	: *Albugo*
Species	: *candida*

Symptoms:

The disease can infect different parts of the plant, including leaves, stems, and flowers and cause both local as well as systemic infections. White creamy, golden elevated pustules on the leaves that eventually consolidate into patches provide evidence of local infection. The affected leaves turn yellow and eventually dry up and fall off the plant. Systemic infections produce swelling and distortion of the stem and floral sections owing to hypertrophy as well as hyperplasia and create "stag head" shape. These infections lead to the formation of characteristic white pustules on the affected plant parts, which can cause severe damage and reduce crop yield.

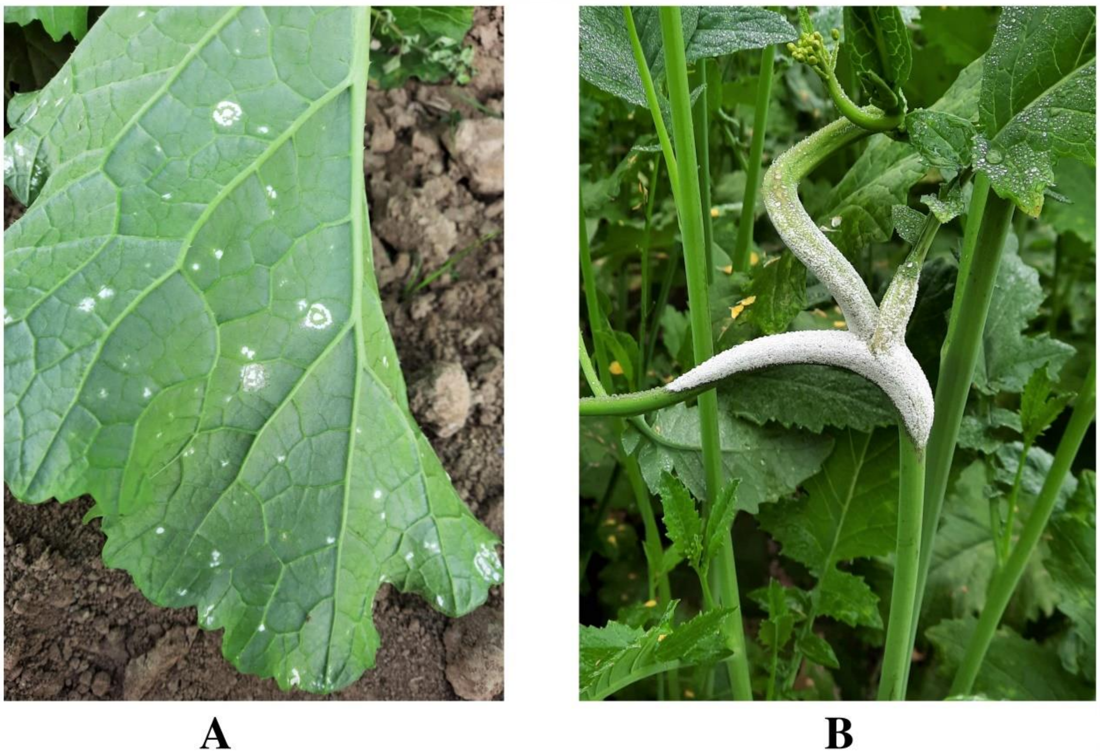

Figure 1: (A) mustard leaf infected with *A. candida*, **(B)** An infected inflorescence showing staghead.

Life cycle:

Albugo candida survives on crop debris or in the soil as thick-walled resting spores called oospores. In spring, the oospores germinate, and the hyphae penetrate the plant tissue through stomata or wounds. The fungus then grows and produces spores called sporangia, which are released into the air and can infect nearby plants. The sporangia germinate on the surface of the plant and produce thread-like structures called hyphae, which grow into the plant tissue and form pustules. These pustules contain spores called zoospores, which are released into the air or splashed by rain to nearby plants, starting a new infection cycle.

Management strategies against White rust:

The management of white rust disease in Indian mustard involves several cultural, chemical, and biological control methods.

Cultural control methods: The cultural control methods include timely sowing of certified seeds, crop rotation, proper sanitation, and balance use of fertilizers. Crop rotation with non-cruciferous crops can help to reduce the inoculum levels in the soil. Field sanitation by removing and destroying infected plant debris also reduce the occurrence of the disease.

Chemical control methods: These involve the use of fungicides to prevent or control the disease. Fungicides can be applied preventively or curatively, depending on the severity of the disease. For example, seed treatment with fungicide (Metalaxyl) reduces the spread of the disease in the crop. In the field, 0.2 % aqueous solution of Ridomil MZ [which is a mix of two fungicides (Mancozeb 64% and Metalaxyl 4%)] can be sprayed when disease symptoms appeared around 35-40 days. The second spray can be done after 10-15 days to control the disease.

Disease resistance:

The interactions between plants and pathogens are critical determinants of plant health and crop yield. Plants have developed a range of mechanisms to resist pathogen infection, which include physical barriers, chemical defenses, and immune responses. The molecular basis of host-pathogen resistance in plants has been extensively studied over the years, and a great deal of progress has been made in understanding the underlying mechanisms. Plants have two main branches of immunity: PAMP-triggered immunity (PTI) and effector-triggered immunity (ETI). PTI is activated when plants recognize conserved microbial features, known as pathogen-associated molecular patterns (PAMPs), through pattern recognition receptors (PRRs) located on the plant cell surface. Effector-triggered immunity (ETI), on the other hand, is activated when plants recognize specific pathogen effectors, which are molecules produced by the pathogen to manipulate the host's physiology and facilitate infection. One of the main mechanisms of resistance in plants is the production of phytoalexins, which are small molecules that are toxic to pathogens. Phytoalexins are produced in response to pathogen infection and can inhibit pathogen growth and spread. Another important mechanism of resistance is the production of cell wall reinforcement compounds such as lignin, which can provide physical barriers to pathogen invasion. Additionally, plants can produce a range of pathogenesis-related (PR) proteins, which are involved in the recognition and elimination of pathogens. The molecular basis of host-pathogen resistance in plants is primarily governed by the interaction between plant resistance genes (*R* genes) and pathogen avirulence (*Avr*) genes. The *R* genes encode proteins that recognize and respond to specific pathogen effectors, whereas *Avr* genes encode the effectors themselves. When a pathogen carrying an *Avr* gene infects a plant that carries the corresponding *R* gene, the R protein recognizes the effector and triggers a signaling cascade that results in the activation of defense responses. The molecular basis of host-pathogen resistance in plants is a complex and multifaceted process, involving a range of physical, chemical, and immune mechanisms. A deeper understanding of these molecular mechanisms will enable the development of new strategies for the management of plant diseases, ultimately leading to improved crop yield and plant health. For Resistance against *A. candida*, the *R* gene *BjuWRR1* has been characterized in an east European line (Donskaja-IV) of *B.juncea*. This gene had CC-NB-LRR domain of the*R* gene and responsible for the resistance against different *A. candida* isolates. Another *R* gene (*BjuA046215*) for *A. candida* resistance was characterized in the Chinese vegetable type mustard (*B. juncea* var. *Tumida*). This gene has a CC-NBS-LRR (CNL) type *R* gene domain and conferred resistance against white rust pathogen.

Strategies for Developing Disease Resistant Varieties:

Developing disease-resistant varieties is a crucial strategy to increase crop yield and quality while reducing the usage of pesticides and fungicides. The development of such varieties involves several strategies, including classical breeding, genetic engineering, and marker-assisted selection.

Classical Breeding: Classical breeding is a time-tested strategy for developing disease-resistant varieties. It involves crossing two or more plants with desirable traits to produce a new plant that inherits improved yield with disease resistance. This process is repeated over several generations to stabilize the desired trait and create a new variety. Disease-resistant varieties can be developed using this strategy by crossing plants with natural resistance to a particular pathogen. The main advantage of classical breeding is that it does not involve genetic modification, making the resulting varieties more acceptable to consumers. However, it is a slow process that can take several years to produce a disease resistant variety, and there is no guarantee that the resulting variety will have durable resistance to the disease.

Marker-assisted selection: Marker-assisted selection (MAS) is a technique that involves identifying specific DNA markers linked to the desired trait, such as disease resistance, and selecting plants with those markers. This technique has revolutionized classical breeding by allowing scientists to select plants with desirable traits without having to wait for several generations to stabilize the trait. The main advantage of MAS is that it allows for more precise selection of plants with desirable traits, resulting in faster development of disease-resistant varieties. However, this technique requires the identification of specific DNA markers linked to the desired trait, which can be a time-consuming and expensive process.

Markers for White Rust: Several molecular markers have been mapped with the white rust resistance in some of the resistant genotypes of Indian mustard. The intron polymorphic markers *AcB1-A4.1* and *AcB1-A5.1* were mapped in the white resistant genotypes Heera and Donskaja-IV respectively. Recently, another intron polymorphic marker *BjuA046215* was mapped in the *B. juncea* var. *Tumida*. Several other white rust resistant markers were developed in other members of the Brassiceae family viz *Raphanus sativus* (*Ac-1*), *Brassica napus* (*Ac2V1*) and *Arabidopsis thaliana* (*RAC1*, *RAC2*, *RAC3* and *RAC4*) respectively. Therefore, developing disease-resistant varieties involves several strategies, including classical breeding, genetic engineering, and marker-assisted selection. Each strategy has its advantages and disadvantages, and the choice of strategy depends on several factors, including the specific pathogen, the desired trait, and the time and resources available. Regardless of the strategy used, the development of disease-resistant varieties is critical for ensuring food security and sustainable agriculture.

Conclusion:

White rust disease caused by *Albugo candida* is a significant fungal disease that affects Indian mustard, a crop of great economic importance. The disease can cause severe damage and reduce crop yield, but its management can be achieved through the application of various control methods. Farmers and researchers must continue to work together to develop sustainable and effective strategies to control this disease and ensure food security for the growing population.

Suggested Readings:

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