WORLDWIDE WHEAT DISEASES THEIR CURRENT STATUS AND MODE OF RESISTANCE: A REVIEW

ABSTRACT

The appearance of more notorious and invincible rust fungi strains and wheat species made several varieties more vulnerable to different kinds of diseases. Fusarium head blight, leaf spotting diseases, root diseases, and recently wheat blast emerging in South America, Bangladesh, and Zambia, largely because had insufficient varieties of resistance. Extensive research has already been performed both on the genetic approach and other quantitative methods for most diseases. A caution combination of type determination and molecular strategies to be able to accomplish long-term resistance and save up global wheat productivity is too promising. With newer versions of sequencing techniques, functional genomics, and bio informatics, wheat genomics has been completely redefined. The sequencing and annotation of the wheat genome just recently has been its staple together with the thorough analysis of gene content among sub-genomes, now we can look forward to a faster understanding of wheat genetics and, as a consequence, a speedier identification of genes providing disease resistance. In addition to that, the molding of the wheat genome sequence has enabled exploration of marker-trait associations, identification of potential genes, and consequently developing Generation Selection (GS) studies. The fast-track sequencer genotyping devices have enhanced genetic diversity estimation, building high-density genetic maps, and the study of polygenic traits in genome-wide association studies (GWAS) and quantitative trait locus (QTL) mappingLacations of registered KASP breeder-friendly Kompetitive allele specific polymerase chain reaction (KASP) markers have simplified the process of tracing and stacking of resistance alleles/genes in existing superior wheat lines. This chapter gives a summation of the key diseases in wheat production, their hotspots, their consequences, and the management plus the green genes methods to strengthen resistance breeding and application of the boosted stems in wheat.

Keypoint: accomplish,Generation Selection,genome-wide association studies,Kompetitive allele specific polymerase

1. INTRODUCTION

It is among cereal crops that stand out, not to mention the significance of wheat as one of such staple food crops which earns its enviable prominence globally through its remarkable role in world food production and nutritious provision among others. What began as a domestication process in southwestern Asia later evolved into a continental variety spanning the entire continent of Asia, Europe, Africa, and the Americas. Whether low, high, arid or wet, this flexible crop has proved to tolerate any climatic condition ranging from alieration to drought and prefers under irrigation(Babu et al., 2020).It is foreseen that due to high livestock farming, more affordable cereal-based crops such as wheat will contribute greatly to this estimated 60% rise in global wheat demand that is anticipated by 2050. Nevertheless, wheat production has to be addressed with unanticipated unfavorable biotic and negative abiotic factors that are influenced by environmental changes or, pathogen outbreaks. These days, monoculture techniques restrict genetic variability present among different modern wheat varieties therefore causing a rise in new crop diseases that threaten even thoughum supplies. Those challenges to be faced by the wheat production which requires a strategic plan in order to guard it from any future negative effect on food security(Bakala et al., 2021). The group of species known as wheat (*Triticum spp.*) poses as one of the main starches for about 2.5 billion people all over the globe who correspond to about 33% of the world's population and from which approximately 20% of the world's major proteins and calories are derived. This as the food security guard stands second only to rice and is a food crop that is the most widely grown in many developing countries; as such, it provides millions of farmers with a viable farming option on wheat(Bhalla et al., 2017).On a global level, the role of wheat as the most traded export commodity, depends on a value of around $ 38. 8 billion in 2019, is of immense significance. Currently the world's largest cereal crop in span of 218 million cultivation area produces an estimated value of 765 million tons of which is monetarily evaluated as US$150 billion(Bhavani et al., 2021). In order to satisfy wheat production quotas of the future the agriculture focus will be on significant increase of production targets past one billion tons, because by 2050 it will be required to feed 9.6 billion of people. With the ever-changing consumer habits focused on wide wheat goods' world chain and quality, high yield and regional adaptation requirements in wheat cultivation in varied wheat fields. In spite the achievement of sustainable gains in genetics, there are challenges like climate change and variety of stresses at both local and global level that pose threats to wheat production which need a proper mitigation measures(Bhavani et al., 2022). Furthermore, the breeding of wheat with high performance cultivars has resulted in the genetic diversity to be narrower, consequently making all types of wheat susceptible to more epidemic pathogens which thus affect global wheat production. Fighting these limitations still occupies one of the top priority goals if we are to provide a secure food supply for the world, for now and tomorrow(Blanco, 2024).

2. THE INTRICATE LIFE CYCLE OF THE PATHOGEN

Puccinia striiformis f. sp. one of barley (Pst), Wheat Stripe Rust better known Pust meant to, to undergo five stages of the spores and relies two plant hosts species to carrying out the lifecycle. The lifecycle of Pst can be broadly categorized into two main stages:The lifecycle of Pst can be broadly categorized into two main stages:

- ### ASEXUAL STAGE (ON WHEAT - PRIMARY HOST)

At this stage of sowing, the seedling triticonose, which is a Triticum sativum disease, generally shews up. It involves multiple cycles of dikaryotic Pst urediniospores (with two nuclei per cell: The life cycle goes forward in andiincomes, thereby the sporulates are splashed to the atmosphere and acted by the wind current to infect the primary host This pathogen is common in ears of dry or wet beans, an infection that destroys cell membranes of host plants and leads to multiplication. This mycelia formation interweaves through the mesophyll cells taking place within as well as between them(Hussain et al., 2022). Haultoria, which are small infection structures, are present here and they serve a purpose of extracting nutrients from the host cell walls. Visible 12–14 days after infection on susceptible mature plants, with symptoms consisting of yellow to orange urediniospores forming blisters along veins, with these blisters appearing as stripes. Infections can be interpreted as further human death can be happened as a consequence of the series of secondary infection. Depending on the resistance level or mild susceptibility, symptoms range from dark spots having no sporulation (indicating hypersensitivity) to strong necrotic and chlorotic patches with slightly limited sporulation(Jia et al., 2018). By the end of the wheat period of growth, a few isolates may be able to create two haploid cells through karyogamy. Subsequently these teliospores germinate giving rise to a promycelium of four cells which perform meiosis, eventually forming a single haploid nucleus linked to the apical cell from which the basidiospore is developed, which is the spore capable of infecting the alternative host(Juliana et al., 2019).

- ### SEXUAL STAGE (ON BERBERIS SPECIES - ALTERNATE HOST)

Pst sexual stages develop on the same Berberis host species, which serve as the alternate hosts. Genetic interaction and gradual variation of Pst will entail genetic recombination and diversity in the course of this stage(Keller et al., 2018).However, much information is still unknown regarding the sexual stage of the Pst, and now, members of the Berberis species are being investigated as potential carriers of the Pst lifecycle along with female rust species Pucillinia graminis f. sp. Numerous studies during the past 2-3 decades have demonstrated that three million people become sick with tritici (a stem rust disease) yearly. In the past, such a thought encouraged authorities in various European and North American communities to remove the plants completely. You may wonder, however, how Blackberries infected with Pst do not exist in the wild(Koutouleas et al., 2024). The abundance scarcity could be attributed to environmental factors, which make conditions neither suitable for two stages separated by almost two weeks and which involve a single structural element telia as well as unstable time periods and optimal germination of teliospores embedded within telia, which happens during the last weeks of the infection season and produce basidiospores, which are within their short viability(Kumar et al., 2022).A study published recently revealed that species of Berberis in the Pacific Northwest are not the great contributors to the YR occurrence in US several areas. On the other hand, new alternate host, Oz Perennial Plant (Oregon grape) would be added to the list. Wheat infection achievement purpose is to provide the sexual Pst stage with the new mixtures of host standing genetic variation. The procedure leads to the transmogrification of new genetically engineered clones which are potent and powerful enough to be responsible for worldwide epidemics and rapid response alteration in efforts to prevent the attacks on wheat resistance capacities(Kumar et al., 2023).

3. EVOLUTION AND ADAPTION OF PATHOGENS

During the late nineties, some countries across the globe, such as Nepal and Pakistan which are in Himalayan region, and the China which is near Himalayan region, did show some notable exceptions in the prevailing low genetic variation of Pst(Kusunose et al., 2023). It was observed that they were areas with heightened recombination, incredibly effective at sexual reproduction, and significant genetic variability, which landed them on the putative origin centers list for Pst.Nonetheless, the era of malicious bastards and the sudden shoot of Pst(Plum Pox virus) in the recent Pst(Plum Pox Virus) has observed. This is an outstanding occurrence as the novel strains, PstS1 and PstS2, spread throughout the U.S., Europe, and Australia within 3 years, at the beginning of the 21st century(Li et al., 2015). The current genetic analysis performed worldwide used DNA fingerprints and detailed virulence pathotyping and discovered that while these two strains were almost identical in the genetic level, they established the divergent path compared to the root strains in their own geographic area. The reported fast transmission of new strains was linked to the evolutionary development of their high aggressiveness (higher spore production, faster symptoms appearance and adaptation to high temperatures) and to detail investigations which were conducted later following this rapid progress of the disease(Luo et al., 2023).

Besides the two standard PstS and PstS2, unusual synthesis of Pst races has been also spotted. The northern healthy Pst population from eastern France displays high levels of heterogeneity and unique clonal population composition, while a single clone isolated from the south persists over time and is also widespread in the neighbouring populations. This southern isolate was observed to be more in genus with nearer to Central Asian-Mediterranean population. The same thing, large DNA segments are reported to distinguish both large and small population of pathotypes from the pathotypes of 'old' Northwestern European population having high genetic variability(Mapuranga et al., 2022).In 2011, two new race Pst types were found that were named after the cultivar on which they were first identified: 'Wolinvibe' and 'Staro' (which is translated as 'the stock'). In theз cases, PstS7 and PstS8 were detected simultaneously in different masks of Europe and affected bag varieties that demonstrated previously adult plant durability. Race clones from both races represented an uncommon type of teliospores for typical European isolates in a way that these clones caused a higher spore number than native isolates. Subsequently, recognition of other races of Pst, including PstS10, (-'Warrior') and PstS4 ('Aggressive of Triticale'), along with an expansion of genetically heterogeneous races, has become the predominant phenomenon in Europe. More interestingly, these variations that were controlled by the genetic diversity studies are tending the scientific community to theorize about a possible aerial-induced foreign incursion as it was the first time set in Europe since the beginning of Peach stalk int as far back as the 19th century. These rapid expansion into other places such as Central Asia and upper African has expanded the population of Pst which is one of the agent causing the YR epidemics(Naseri & Safaee, 2023).

4. THE INFLUENCE OF BIOTIC STRESSES ON WHEAT PRODUCTION

Around the globe, wheat production is disturbed by pests and diseases resulting to a large extent in 20% lost yield generation annually. One major loss was caused by the occurrence of "Leaf Rust" in 1938 after the susceptibility of the wheat variety "Thatcher" revealed itself. Therefore, the rust eroded hectares of wheat in millions over in North America. As a result, leaf rust distant itself in regions such as the USA, former USSR, and China equally as constantly as before and turns into a significant economic pressure(Nigus et al., 2023).Efforts to develop leaf rust-resistant cultivars at institutions such as the International Maize and Wheat Improvement Center (CIMMYT) have shown promising returns, with a cost-benefit ratio of 1:For instance, educational programs, public lectures and workshops, or even comprehensive books are frequently added to these efforts with the objective of multiplying the effect of the campaign 32. The disease does not actually reduce the quantity of grains per unit area but rather affects both the amount and the weight of individual wheat kernels. USA experiences loss of more than 350 million USD between 2000-2004, just leaf rust just would be one of them. The same amount of loses has also occurred in Mexico during from 2000 to 2003 and reached to US$40 million between 2008 to 2009. In South America, e.g., Argentina, Brazil, Chile, Paraguay, and Uruguay, losses caused by intolerable yield depleted an immediate sum of US$172 million between 1996 and 2003(Pfrieme et al., 2023). As much as 3 million tons in annual yield loss has been manifested on the Chinese soil, and a 25% yield loss in Pakistan's wheat cultivation due to the leaf rust infestation was as much as $86 million in 1978. Australia experiences up AU$197 million in annual total yield losses on susceptible cultivars from mauve; nevertheless, if cultivars resistant to the disease are adopted, losses will be substantially reduced to only about AU$12 million(Randhawa et al., 2019).

Also among those holdovers was stem rust, a dreadful menace that wreaked havoc in the USA in the first half of the 20th century, ravaging yields to the tune of 20% at the peak of the epidemics occurring between the 1920s and 1960s. Incomes of Scandinavians dropped significantly by between 9% and 33% in 1951, while eastern and central Europeans say they were 5–20 % lesser in 1932. Severe stem rust epidemics happened in different parts of China during the cropping seasons of 1948, 1951, 1952, and 1956 especially in the north of the county and Inner Mongolia. In the case of Canada, unpredictable plague rust epidemics affected western parts of the country, wreaking havoc with estimated losses of at least CA$175 to CA$233 million and the development of the National Phytopathology and Rust Control Program. Researchers recently estimated that the wheat yield loss exceeding 6.2 million tons worldwide could annually amount to US$1.12 billion. This is almost equivalent to the global wheat export value of 2019(Rasheed et al., 2018).

5. SIGNIFICANT BIOTIC FACTORS THAT RESTRICT WHEAT PRODUCTION IN VARIOUS ENVIRONMENTS

The human sources of intensive wheat cropping systems encounter a lot of problems due to different fungal pathogens that use two principal strategies of plant pathogens, biotrophic and necrotrophic. In addition to pathogenic fungi, the Blumeria graminis form powdery mildew, Puccinia graminis tritici produce stem rust, Puccinia recondita/ Puccinia triticina turn into leaf rust, and Puccinia striformis cause stripe rust. Apart from the residue-borne quintessential pathogens like Pyrenophora tritici-repentis which causes tan spot, Mycosphaerella graminicola causing Septoria tritici blotch, Phaeosphaeria nodorum causing Septoria nodorum blotch, Cochliobolus sativus causing spot blotch , and Fusarium graminearum andSeed dressing, the low productivity and non-smut regions caused common bunt that is caused by Tilletia caries and bunt which caused by Tilletia indica as well, can be of major importance in important regions such as Karnal bunt(Rebouh et al., 2023). While above 50 viral wheat species diseases are also reported, though their importance is clinically limited to certain zones of the world usually causing productive loss. Respective viruses such as the corresponding genera Bymovirus of the plant Potyviridae family, or the genus Furovirus of the plant Virgaviridae family, the root infecting plasmodiophorid Polymyxa graminis, as well as the insect transmitted viruses; for example, Barley Leaf Yellowing (BYD) caused by luteoviridate group Moreover, it should be noted that Tritimovirus' group, which is classified in the Potyviridae family, is Wheat Streak Mosaic Virus (WSMV) and is another well-known viral disease of wheat. While wheat pathogens can be either fungi, viruses, or bacteria, we need to have a good understanding of them before their disease management strategies. Implications of economically significant diseases concerning the agro-ecosystems of major wheat-producing nations have been discussed in length so as to guide against the losses they pose(Savadi et al., 2018).

6. RUST DISEASE AND ITS TYPES

The two species of rust fungus, which attack the wheat crop, constitute a significant issue for growers of wheat across the globe. These pests lead to a reduction in produce volume and this result is quite a headache not only to farmers but also for the people at the end of the chain. It is thought that damage inflicted by wheat rusts is reported to be between US$4.3 to US$5 billion on an annual basis. The diseases of rust recorded in the past are known to be an old enemy of wheat, which could be one of the earliest pathogens that took hold of their nutrients system hence, destroying it. Spores of stem rusts dated back to circa 1300 BC, and their existence in Israel was reported having severe influence on cereals in this region, Italy, and Greece(B. K. Singh et al., 2023).There are three main types of wheat rust diseases: it's important to emphasize that as of now there are three types of rust that appear in different colors in different places across the world, which is the stem (black) rust, stripe (yellow) rust, and leaf (brown) rust. From the group of Basidiomycota, genus Puccinia, these three diseases have been identified and were called P. graminis f. sp. By implementing these resistance races along with sufficient surveillance, we can stamp out multiple wet spell-induced epidemic outbreaks of stem rust caused by P. tritici (Pgt) and stripe rust prompted by P. striiformis f. sp. wheat Stripe Rust and Wheat Leaf Rust respectively caused by P. striiformis (Pst) and P. triticina (Pt) fungal disease. All species of rust pathogens during their outbreaks account for considerable loss of wheat genotypes and, as such, are critical issues to farmers around the world.

- ### STEM RUST

Stem rust, another plague, is often found in warmer geographical regions and is primarily detected at later stages of growth. SR may be the single factor which underwent the catastrophe possibility in a regular and healthy crop yield during an outbreak, with rigid yield losses observed. At the initial stage of the disease, the inflorescences will be shrunken or de-grained and thus, more missing grains result in the loss of yield. World SR diplomacy and the worldwide efforts have a massive impact on successful implementation of global action strategies to curb SR epidemics. Some of these interventions are: elimination of barberry species between the years of 1918 through to 1980 in the USA and its domestic country, employment of wheat germplasm carrying broad effective SR genes, and the use of fungicides.While SR was successfully controlled over thirty-year practice, variant "Ug99" emerged as an existential threat for world wheat and once again, it has become a challenge to achieve effective control of this disease. The race Ug99 (TTKSK) shipped countrywide and upon encounter of over 50% of the known Sr resistance genes including programmed genes like Sr31 and Sr38 among the widely adopted genes, it has developed unique virulence. Rogue strain (Ug99) was first seen in 1999 when it was detected in Uganda, since then it has affected bagrgrounds of whole Africa and the Middle East. The TTKSK-race root is speculative, and the distinguishing genetic characteristics of it from other stem rust hint at the possibility that it did not undergo selection process among races of Pgt. Certain novel tehnoumatic combinations within the Ug99 race group can now overcome effective resistance genes, not only in East Africa, but also threatened production in other wheat producing regions(J. Singh et al., 2023).

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Stripe rust (E, radiation, also known as yellow rust, is a common disease not only in nearly all the zones of wheat growing, but also in wheat production areas. The race of the sense of sight is characterized by its ability to tolerate lower temperatures, accompanied by well-humidified weather, and in the last decade by its adaptability to the areas of moderate climatic conditions, situated far from the equator. The species able to endure the elevated temperatures were those that have migrated to the spots where the temperature is pretty high, including these moving between different growing regions. It is that this drift leads to susceptibility of various cultivars to the disease when this appears on the proliferation stage. In the course of years, new races with increased frequency for virulent strains within the Pst per se have come into being and popular wheat varieties have become more vulnerable to these harsh effects. An estimate of 5.5 million tons of YR yearly worldwide being lost in the field is the latest available statistic. In North America alone, even before the 2000s production number dropped below 1 million tons, while in China, losses of yield could be in range of 1.8 to 6 million tons depending on the spreading of the epidemic. As in Europe where recent observations of yiel deficits to have been partly blamed hatefully to come from the region within the Himalayas. In the meantime, the effect of arose races of newly bred YR on the output of wheat is erratic. These new incursions are unfortunately more often combined with acts of widespread destruction. For example, introduction of Japanese citizens to eastern and western Australia in 1978 and a few days later, in the first decade of 2000s led to the serious damage. Native people in America have been replaced by immigrants from exile after 2000, while European Rast reach in 2011 and 2012 has been inundated by invaders from the Himalayan, resulting in significant race shifts in host susceptibility. The latest researches reveal both pathogenicity and social trends as related to the different and geographical areas flooded with YR. It found out, for instance, that the highly diverse pst races belong to different genealogical lineages with the most aggressive types well-adapted across a range of environmental settings that had spread wide across numerous regions across the continents(Singh et al., 2016).

- **LEAF RUST**

Leaf rust (LR), the brown rust (BR), as is known, is the most common rust fungus species which causes damage and growth restriction in winter wheat, spring wheat, and durum areas also. Under failed LR, the impact of yield losses can be great, especially when infections occur early and are then accompanied by conducive conditions which facilitate rapid disease progression. The deficit mostly gets generated due to a decrease in an average number of grains per tiller and smaller grain masses one tiller poddles.LR is subject to widespread changes, warming or hot in nature implying affected regions being vast across the US, Asia Pacific Region, Russia or central Asia to Mexico, southeast US, Uruguay, Argentina, Turkey, China and Europe. The particular type of LR pathogen Pt is either existing in tetraploid durum wheat or hexaploid common wheat and races conferring virulence on several LR loci are acclaimed most wherever rye is grown. The Pt races, high in virulence that originated in early 2000s and spread in a virulent pattern across South America, Mexico, Europe, the Mediterranean basin, and the Middle East among other regions is nothing but an expression of distress to the world.At a global scale, the various populations of Pt show their genus specificity in virulence and molecular genotype. Unlike variation and selection which occur among specific environments, conventional evolution, migration of Pygmy races from various continental regions is the most probable and recent scenarios. Beginning from the mid-1990s, isolates of Pt with the virulence to particular LR genes have been more and more. Consequently, these have been found in different regions of North America, Europe, South America, Ethiopia, Turkey, and Pakistan. The isolates of this type tend to be associated with unique molecular genotypes, which are the telltale signs of the current arrivals to the regions. Moreover, Pt-virus isolates, which are and or closely related to the diverse backgrounds, are now found in Middle East, South America, Europe, Ethiopia, Tunisia, Mexico and the US since the early 2000's(Sun et al., 2023).

7. OTHER WHEAT DISEASES

- ## POWDERY MILDEW

Made by Blumeria graminis f. sp. Is one of the things that causes powdery mildew. unlike the rust diseases, tritici spreads rapidly under the moist climate that is either rain-fed or linked with irrigation, which in turn stimulates the incidences of the pathogens. Nitrogen application is the main factor responsible for the disease tightly linked with that, with the application of excessive nitrogen fertilizer leading to a severe flood of disease. What it offers is that warm and rainy regions of Asia, for instance, Japan, North and East Africa, and areas with dominant cold and humid climates of Europe and America, are in the front line. The story of the plant life cycle where powdery mildew begins to appear in early stages may lead to the growth of tillers that use up the stored food instead of grain yield. In homogenous populations, even small presence of drawback in resistant shape leads to lower yielding. By and large predicted yields are achieved when taking into account the ratings of leaves for susceptibility at the initial Feekes stages with the most serious yield reductions observed when significant amount of disease in question at Feekes 10 (booting stage) and Feekes 9 (expanded flag leaf). Timely identification of the disease is thus paramount and an application of fungicide at Feekes stage 9 or earlier is preferable as a way of getting around this yield loss. Lags of up to 40% have been detected, with a drop in average seed size and number per unit area are the dominant traits, and the influence of host resistance/susceptibility on the population of a mixture largely predetermines the degree of damage inflicted on the crop. However, the reduction probability of flour protein will not be apparently impacting milling and baking quality proceeding(Tadesse et al., 2016).

Fusarium Head Blight

EU blight (FHB) has a high position among a host of other diseases that have evidently affected wheat agriculturally worldwide, with the major epidemic zones being in the North America, Europe, Asia, and South America (Southern Cone). Even though many strains of Fusarium are responsible for FHB, it is the Fusarium species complex that serves as the most important and is found in all regions of this global concern, including the major epidemic regions.FHB is a prevalent disease in the spring and summer, where the disease experiences a peak development period during the flowering stage of wheat, causing large losses in harvest yields and quality. The fungus represents another danger by producing mycotoxins (including deoxynivalenol or vomitoxin) which are very toxic and harmful not only for people but also for animals. It becomes very clear why the apprehension about food and feed safety is warranted. International standards and regulations concerning the maximum allowable concentration of DON in wheat grain and its final products are in effect in many countries. But when the allowed level is exceeded then it can cause drop in price by a big margin. According to the study for the USA period 1993-2001 FHB-related losses in wheat and barley resulted in this significant amount as much as US$7.67 billion. China has probably seen a huge growth in FHB epidemics in the last two decades with affected areas ranging from 5.3 million hectares to 9.9 million hectares in an average year and a record high of 9.9 million hectares in 2012 during the epidemic. FHB has yield losses that may be up to twice as big as that of rust where the reduced crops can be as low as 50–70% especially in Europe, North America and South America ongoing(Wulff & Krattinger, 2022).

8. DISEASE RESISTANCE

- ## THE MOLECULAR UNDERPINNINGS OF WHEAT DISEASE RESISTANCE

Since wheat was produced through a hybridization of different species or genera thus becoming an allopolyploid, it possess high genetic diversity, which helps the crop to fully adapt to a wide range of environments. Being a very broad high ealtioned crop, wheat is being everytime exposed to a wide range of parasites and pathogens more of which can spread around globally. With their immune systems becoming more complicated through millions of years of coevolution with diseases, these plants have developed a defense mechanism. This immune system times happen among gene for genes interactions, where some plant resistant genes against a certain disease (R-genes) interact with corresponding avirulence genes (A-genes) in the pathogen. The plant immune system consists of two main components: pattern-recognition immunity (PTI) or effector-directed immunity (ETI). PTI becomes triggered when investigate plant receptors recognize microbial or pathogen-associated molecular patterns (which are known as MAMPs or PAMPs). Otherwise, ETI entails perceiving evoked effectors of pathogen by plant immune receptors including conserved domains such as NBARC and LRR (NLRs). It is common knowledge among biologists that the two domains have a function of recognizing NLRs. Antibiotic treatment sometimes triggers an extratoxic-state that is characterized by hypersensitive reactions (HR) at the infection site(Yigider et al., 2023). Thus, the wheat holds many genes that confer biotic stress resistance, but only a small bunch has been isolated and subjected to cloning. Such genes are very diverse sources of genetics including various species from the primary gene pool (e.g., Triticum spp.), secondary gene pool (example with T. timopheevii), and the tertiary gene pool (considering Aegilops, Secale and Thinopyrum). These genes are the key element in the genetics that improve the level of wheat resistance to pathogens and peste, that's why the agriculture productivity is maintained on a global scale.

- **INSECT RESISTANCE IN WHEAT**

The responses that govern insect resistance in plants can be broadly categorized into three main types: reservoirs, tolerance, antibiotic, and antixenosis(Zhao & Kang, 2023).

TOLERANCE

Resistance in a plant is the amount of damage caused by insects without having a considerable structural failure. With genetic make-up as an intricate network of specific traits made insect remaining a beautiful picture without interfering with production. The term tolerance just does not favor the spread of insect pests and thus does not provide them selective pressure. A part of crops and plants actually remains sensitive to insect damage.

ANTIXENOSIS

The antixenosis is a countermeasure that happens when plants are unappealing or nasty for the stems, causing lesser meals or the removal by insect pests. This can be achieved through genetic differences in the chemistry of plants, for instance, which make them chemically inedible, or through plant structure such as plant surface texture. Que antixenosis can be involved as a main factor in lower insect to crop damage.

ANTIBIOSIS

In the context of antagonism, inhibited growth and reduced fecundity of ruggedly edible plants by insect pests is known as antibiosis. The decrease could translate into a shrinking of the adult populations, a delayed development of insects, or a fertility shortage. Antibiosis is perhaps the most important form of resistance to insect pests involving plants with a mean contribution of around 90%, the cases have been recorded to be in the field.There are three mechanisms involved in this collective and this recruitment forming the overall plant defense against insect pest. Explaining the influenced mechanism can be used when developing the methods of insect resistance of crop through breeding or the biotechnological approach.

9. CONCLUSION

The issue of wheat pathogens is becoming more and more complex, and therefore it is necessary to take efforts to reveal new ways of controlling this disease and the breeding of resistant wheat. While epidemics of severe diseases are not observed in recent years and genetic variability in cultivated varieties of wheat is not that important problem, the two dynamic factors still remain a challenge - the investigating pathogens' ability to bypass the resistance of wheat cultivars and the lack of genetic diversity among them. Seed resistance is brought about by introducing race specific and APR genes with the selection of a wide germplasm base. While this rapidly evolving race of new pathogen genes that can overcome the race-specific resistance genes can result in extensive susceptibility of varieties to them, plant breeders have developed methods to slow this down or at least to delay this race. To solve these challenges by improving the productivity of wheat and staying clear of factors causing crop losses, the breeding strategy must be strengthened for developing strong multi-resistant traits that resist all diseases. Combining novel genomic methods, including NGS, and phenotypic selection offers an optimistic prospect of making the grain tolerance of the species serve not only for diseases but also for various other essential purposes. Having wheat genome reference and genetic mapping technologies enables the interregional finding and cloning of genes promoting rust resistance in a matter of time. However, the latest development in wheat transformation methods is another chance to add high resistance genes or gene clusters choice using a very specific functional marker. This strategy help breeding resistance to factors that influence the manifestation of resistance in a certain way on the basis of a variety of mechanisms of disease resistance expression. The policy world would dictate the destiny to use transgenic cassettes as a tool for developing the cultivars' resistance against diseases in a specific country or worldwide. With the use of modern molecular techniques and conventional breeding practices, scientists and breeders can significantly speed up the breeding process of wheat species that are either resistant or tolerant to diseases. Hence, they can contribute in leading to a global food security as well as developing the farmers.

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