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Host factors influence the pathogenesis of *Tilletia indica*: A review

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Abstract

Wheat is a staple food in the world and world trade for wheat is greater than for any other cereal. It is known for its good adaptability to certain regions; however, it is affected by many more diseases such as rust, smut, etc. Similarly, a very important fungal disease is known as Karnal bunts (KB) since it affects the grains and is caused by *T. indica*. In the severity conditions of pathogenesis, it poses a big hurdle in trade since it changes the palatability of wheat because of the variability of nutritional factors. In the beginning, only infested a few seeds. Therefore it is very interesting here to understand more about the causative factors that play pivotal roles in the diseases either endogenous factors or external factors. However, researchers have shown that the autogenously factors so-called host factors are more prominent for the disease incidence with respect to exogenous factors.

It has been known that the host factors significantly play an important role in different mycelia development. The changes in monsporidial strains of *T. indica* with molecular signaling which is directly and indirectly related to the pathogenicity in wheat grain in an inductive manner. Here the innermost causative agents are more prevalent which are extracted from wheat spikes and are heat labile for the pathogenesis. It has been also shown that the same endogenous factors increase the mycelination of the fungus. Therefore pathogenesis of *T. indica* by the interaction of molecular signal (s) with host factors could be a key player for disease incidence in the developing grains, which accelerates the quarantine issue by exporting the wheat from one country to another country. So by this review, one can understand more about the disease occurrence in wheat since it is very one of the most important cereals in the world.

Key Message: Host factors play a pivotal role in the development of Karnal bunt disease in wheat due to the interaction of various molecular signal(s) that leads to an important quarantine issue for exporting wheat from one country to another country caused by the fungus *Tilletia indica*.

Keywords: Host factors, *T. indica*, Karnal bunt, pathogenesis, disease management and quarantine issue

1. Introduction

The importance of agriculture was known for thousands of years back however systematic development of agriculture took place only more than 100 years back by the realization of the economic growth and development of the nations. In thumb rule, the total production of agricultural produce plays a crucial role in the long-lasting sustainable increment of the national income of the county. If we talk about the world scenario of different food grain production among the cereals one of the promising cereals would be wheat. The global wheat production in the world is about 786 million metric tons in 2023 (FAO 2023) [24]. However, the world population also increasing parallelly and it will rich more in the future than we have now today therefore wheat production requires more in the future. World trade for wheat is greater than for any other cereal. It is consumed mainly in the form of bread' and chapattis apart from biscuits, cakes, pastries, and alcoholic beverages.

It is known for its good adaptability to certain regions and was the first crop to attract the attention of Indian breeders. However, the total production of wheat in India was about 112.74 million tons in 2022-23 (<https://www.cnbc18.com/economy/indias-wheat-output-set-to-touch-a-new-record-at-11274-million-tonnes-in-2022-23-agriculture-ministry-16766831.htm>).

In future we need to increase the production of wheat more than 112.74 million tons of in future. However, wheat is affected by many more diseases among these a fungal diseases KB play a crucial role as a concern to yield attribute (Mitra in 1931 in India). The fungus belongs to a basidiomycete, which infects the kernels and obtains food from the endosperm. It is the seed-, soil- and air-borne pathogens. It is floret influences disease and infected the grain by sporidia when it comes in contact with the developing ovary. It spread through teliospore onto the field.

Infected grain loses its quality and palatability of the flour due to the fishy smell in the presence of trimethylamine which has quarantine losses. Therefore, it is important to know about the fungal pathogenesis in wheat. Therefore the host system is a limiting factor in the export of wheat since pathogens threaten many problems for the certification process. In the disease management system still, there is no fully secure proof mechanism available to reduce grain loss therefore it is need to know about the diseases. This fungus could be a good study system for concern to know about the incidence of the disease in wheat. *T.indica* can be grown in pure culture, natural or artificial media for generating teliospores, primary sporidia, or secondary sporidia under laboratory conditions. The *Tilletia indica* pathogen is very important since it is directly related to the quarantine issue.

These Fungi, like plants and other organisms, use signaling genes that respond to changes in the environment and set off a signaling cascade that alters the expression of their genes.

The molecular mechanism of these diseases is not clear, however, some important molecular mechanism has been known such as map kinase modules, Adenosine monophosphate-related mechanism, etc. After the knockdown process of the main molecular pathway in *T. indica* losses the incidence of the disease in the host. In the *Magnaporth grisia*, the same mechanism has been shown as a concern for the pathogenesis of the fungus. Furthermore not only in the pathogenesis but also in other process like the fusion process also has been reported the different gene loci although is not directly related to pathogenesis. It has also been shown that the host factors somehow modulate the incidence of pathogenesis in the susceptible wheat host by positively regulating the TiFus3 and TiPmk1 gene expression in the *T.indica* (Gupta *et al.*, 2012) [29]. Keeping in view of the above, known facts we summarize the Karnal bunt as an important disease to understand the pathogenesis and its management for helping the farmer community.

2. Host factors for pathogenesis of fungus *Tilletia indica*

Many researchers it has been shown that endogenous factors could be a key player in pathogenesis in various fungi such as *Fusarium* species (Strange, *et al.* 1974) [71], *Alternaria* species (Channon, 1970) [15] etc. From this observation, it suggested that the autogenous compound of the susceptible host can be considered auxotrophic for this plant product to its parasitic growth and development. Since the host factors are not clearly understood to date, therefore possible factors could be the plant origin growth regulators which are inducing the pathogenesis in wheat by the modulating of many more down-regulating molecular pathways (Strange, *et al.* 1974) [71]. Or it may be some other factors like the nutrient-based factors so deficiency conditions of nutrients may trigger the incidence of disease in the susceptible host and the reason could be the requirement of the special nutrient-related autogenous compound for the growth and development of the fungus *Tilletia indica* in the temporal and special manner and finally stimulates the pathogen response physiological processes like the high respiration rate in the wheat host.

It is somehow correlated with the known facts which have been explored by the researcher that in the pathogenesis conditions, there is more rate of metabolic process like respiration. It clearly suggested that heavy pathogen incidence require more energy sources for the sustainability of the fungus pathogen in the form of carbohydrate which is

immediate sources of energy. Might be other energy sources also required for full growth in the development of *T.indica*. It has been also shown that in many cereals crops diseases, causative biotic agents like the fungus and others can, directly and indirectly, impede the reproductive part of the host plant system, for example, corn smut and in severe cases of pathogenicity can finally kill the embryo, and damaging the seeds because embryos are the part the seed. Similarly, it could be possible in the case of KB diseases in wheat. Therefore the endogenous compound could be the crucial factor for the incidence of the Karnal bunt disease in susceptible host plants.

3. Fungus disease and its history

This Karnal bunt disease progresses systematically to another floret within and then to adjacent spikelets, or even to alternate sides on the same susceptible host (Dhaliwal *et al.*, 1983, Bedi and Dhiman., 1984, Warham and Cashion., 1984) [20, 8, 73]. The researcher has shown that the pathogen infection showed tissue specificity, as just before the thesis of flowers (Kumar *et al.*, 2000) [43]. The boot emergence stages (S2) were more susceptible than the other two stages such as the boot stage (S1) and, the seed forming stage (S3) (Bains, 1994) [7]. This disease was first reported by Mitra in 1931 on wheat caused by *T. indica* (Mitra, 1931 & 1935) [47].

4. Pathogenetic stages, dispersal and proliferation of *Tilletia indica*

The pathogenesis phase in the fungus *Tilletia indica* is very crucial since the said is governed by both endogenous as well as exogenous factors. However in the presence of autogenous factors so called Host factors the proliferation of the myceliation is very high. It finally leads to the development of the teliospore which is present in various forms and its size range varies from twenty-two microns to about forty-nine microns encompasses a sheath of two to four microns and is embedded as a different coating such as perisporium, episporium endo peridium (Khanna *et al.*, 1966) [38]. Its life cycle is divided into two phases one is a diploid stage condition and the other is in the haploid stage phase. During in diploid phase where the genetic constituent in double amount finally goes through the meiotic division in teliospores and comes into haploid condition as a promycelium. This is a continuous process and exists in a dynamic form goes in primary sporidia and then secondary spores and this is the only causative stage that finally leads to Karnal bunt diseases in the susceptible wheat varieties (Dhaliwal and Singh, 1988; 1989) [19, 18].

5. Mating type switch and fungal genetics

From para four, we could understand the incidence of Karnal bunt disease in susceptible wheat varieties because of so many factors. Among them, one of the promising factors could be Host factors. The same endogenous causative agents somehow modulate the sexual phase of the life cycle of *Tilletia indicia*. The mating process in the same fungus also influences by many more fusion agents. These crucial agents play a pivotal role in the myceliation process in the pathogen *Tilletia indicia* that finally triggers the pathogenesis in the wheat varieties starting from the developing grains which finally spread consequently other parts of the wheat spike. During the mediation action sequencing, it goes into the haploid and diploid phases of the fungus. In this way, with

chance factors, any two compatible haploid phases can fuse during the mating process and it is a bit complex phenomenon as far as concern to its genetics since it is happening with the involvement of so many alleles and the same mating process has been shown by Raper (1966) [60].

The fungus *T. indica* is heterothallic in nature and testing for compatible monopodial lines for variability is laborious and difficult. Till now cultures from single teliospores are being utilized but for long the spores will remain at the same pathogenicity level on a particular host needs to be investigated. Only compatible monopodial cultures are able to produce infection and a more or less similar phenomenon was also reported by Royer and Ryter (1985) [61] and Aujla and Sharma (1990) [2] in the same fungus. The molecular genetic variability is in complex in nature many researchers do not agree on the designation of specific races (Partridge, 1997) [54]. Therefore here much more molecular genetics process needs to be explored to understand the clear mechanism of the disease incidence in wheat. Although the draft genome of the fungus *T. indica* has been sequenced many more mechanism is not clear.

6. Virulence of *Tilletia indica* and MAP Kinases signaling in fungus

The Karnal bunt disease of wheat is a Host factors driven disease and the causative biotic agent is the fungus *Tilletia indica*. The severity of the diseases in susceptible host wheat is directly related to the virulence level of pathogens. In the life cycle of the pathogen, it has been shown those both haploid and diploid phases play a role during the mating of the compatible mycelium and finally, regenerate the basidiospores. Researchers reported that the mating required MAT α and MAT β stages. MAT α generates mycelium in low food availability in lab conditions like the lesser amount of N2 and monosaccharide-like glucose in hard environments. As far as concern to molecular signaling in pathogenesis it has been observed that the cyclic-adenosine monophosphate-like molecules play a crucial function in the fusion of the computable mycelium in the fungus *Cryptococcus* species and can cause diseases in susceptible people throughout the world. These studies show that the here the involvement of the gene GPA1 and GPA1 gene have diverse roles in environmental signaling finally helping in the pathogenesis of fungus. Detailed analysis of this gene suggested that it is encoding the subunit of the G protein and the same protein has a role in the cyclic-adenosine monophosphate-dependent signaling pathway. When the same gene GPA1 mutated in the same fungus there was no pathogenesis in the susceptible people and raring the original phenotype after the complementation of the same mutant. It clearly suggested that this gene has wide applicability as a concern to disease incidence in appropriate hosts.

In order to understand the molecular mechanism behind the pathogenesis of *T. indica* in wheat it is very obvious here if something is happening at the molecular level in the same fungus or in the related fungus in which some homologs are there. With the continuation of the same theme, scientists reported that different mitogen-activated protein modules in yeast fungus *Saccharomyces species* (Herskowitz, 1995) [31]. It has been also shown that the different mitogen-activated protein kinase modules have a wide range of functions in different hosts for example *SMK1 mitogen-activated* protein modules kinase plays an important role in the sporulation of

the fungus. Similarly, mitogen-activated protein kinase modules were also reported in fungus *N. crassa* of about three modules one like the mitogen-activated kinase- 2 modules. These modules have similarities with yeast Fus3p and are responsible for the mating process in the same fungus. Furthermore yeast Kss1p, also have a similarity with mitogen-activated kinase-2 modules of *N. crassa* and plays a pivotal role in the formation of the filament in the fungus. Moreover, the c-AMP has also been identified in other fungi like *ustilago* species which is required for the conversion of formation of bud to the filament formation. Two G-proteins Kas 2p and Gpa 2p are thought to influence the c-AMP amount which finally positively contributes growth and development of fungal pathogens in the molecular-dependent process. The above mention report clearly suggested that for the pathogenesis of *T. indica* in wheat it required many more molecular signaling pathways to modulate the disease's incidence in susceptible hosts.

7. Conclusion and future prospective

Here this review summarizes an economically promising wheat cereal infected with fungal and host factors that have an important role in the pathogenesis of the developing grains. Host factor(s) play(s) an important role in the induction of mycelination of the fungus and increase the disease incidence of Karnal bunt. At this moment for the disease incidence, molecular induction cascades as well as environmental modulations either physical or chemical form apart from host factors are important. Therefore here we try to summarize more about the host factor(s) that leads to pathogenesis through signal transduction cascades (MAP kinase pathway). Although the real mode of action of endogenous causative agents besides their nature is not known so far, the present review throws light upon morphological, biochemical, and immunological changes with respect to the exposure of the said agents. Hence in summarized form, it can be said that in presence of autogenous factors imposes a high proportion of virulence intensity with fungus pathogen and causes the appearance of Karnal bunt. However, it needs more intensive integrative study by molecular approach, biochemical apart from physiological to understand the pathogenesis of *Tilletia indica* bit detail for the proper management of disease to fill the gap in the present context of quarantine losses. Moreover, the characterization of host factors for pathogenesis to different management practices is an important issue to be addressed here so that reduces the quarantined loss.

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