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Rice Blast Disease (*Magnaporthe oryzae*): A Menace to Rice Production and Humanity

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Authors' contributions

This work was carried out in collaboration among all authors. Authors GOA and MSA managed the literature searches while authors EFO and SOA proofread and rearranged the review article. All authors read and approved the final manuscript.

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ABSTRACT

Rice blast disease is one of the major constraints to rice production, threatening food security globally. Rice grain production losses due to the disease leads economic losses to the farmers, and to an increase in global rice price as a result of the supply that is far below the consumer demand. The losses from the disease annually was estimated to feed over 60 million individual. The disease has been studied comprehensively by researchers due to the importance attached to rice and its vast spread and destructiveness across the globe. A good understanding of the pathogen causing the disease, its life cycle and development, epidemiology, symptoms, management strategy will offer a good insight into the disease incidence and give an appropriate and effective decision-making in its management. Different control measures have been adopted managing the disease, including the use of resistant varieties. Integrated disease management strategies coupled with good agronomy practices are required for successful control of rice blast for food security. This review, therefore, examined the fundamentals of rice blast disease (*Magnaporthe oryzae)* and offered strategies to minimize the disease activities to ensure proper production and increase the supply of rice grains.

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1. INTRODUCTION

Rice is a cereal crop that is commonly grown globally [1]. More than half of the world population depends on rice as their staple food [2]. Childs, 2004 reported that almost one billion households depend on rice cultivation, its processing and marketing for employment and livelihood across Asia, Africa and the Americas. Rice as a staple food occupies a prominent place in the human diet as the grain form a rich calorie source. It was estimated by the International Rice Research Institute, Philippines that rice production has to increase by 33.3% by the year 2020 to meet the demand of the world population. Shortages of annual increase of rice grain have been estimated to be from 400,000 tons in the year 2016 to 800,000 tons by 2030 [3]. Its production rate in Nigeria has been reported to be lesser than its consumption rate, four in millions metric tons was produced in Nigeria while the consumption rate was seven millions metric tons 2018 [4] thereby resulting in the scarcity of the product leading to competition among the consumers and an increase in price. In some developing countries like Nigeria, rice is now a golden meal amidst low-class citizens.

Rice production across the globe is affected by various biotic and abiotic stresses [5]. Rice blast disease is recognized as the most dangerous and destructive fungal disease among the biotic factors affecting rice production [6,7]. This disease has been reported to cause up to 70 to 80% grain loss whereas some authors report yield losses of 100% i.e total loss during the epidemic growing season [8-10]. Rice blast disease infects all rice plant parts except its roots, and the highest losses in rice grain yield are associated with neck blast [10].

The severity of the grain yield loss from rice blast disease depends on the susceptibility of the variety grown, prevailing environmental condition of the area, the degree of infection, inoculum load on the field and timing of controlling the disease. Blast destroys rice that can feed over 60 million people for a year which is estimated to be more than 70 billion dollars [11]. Rice blast has been recognized as a threat to rice production, its sustainability, global food insecurity and humanity in general. The knowledge of rice blast disease management is essential to avoid further biomass accumulation, grain yield loss and unwanted expenses by the growers or farmers. This knowledge will not only bridge the wide gap between its supply and demand but also reduce the cost of production, reduce rice grain price and sustain food security. The use of resistant variety is another promising way of managing the disease though the varieties are not readily available for the growers. The aim of this review is (i) to know about the rice blast disease and pathogen; (ii) to know the effects of rice blast disease on rice productivity and (iii) to understand the various management approaches to control blast disease for rice production sustainability.

2. THE PATHOGEN BIOLOGY

Rice blast disease is caused by *Magnaporthe oryzae, previously also named Magnaporthe grisea* or *Pyriculariagrisea* [12]. The pathogen, *Magnaporthe oryzae* was referred to as new species [12] after being separated from *Magnaporthe grisea* based on genealogy and mating experiments findings. The two pathogens infect different grasses, *Magnaporthe grisea* was found to infect crabgrass while *Magnaporthe oryzae* infect cereals like rice and millets. This pathogen, *Magnaporthe oryzae* is filamentous ascomycetes in nature with the capability to produce sexually and asexually. The fungus conidia size is 20-22 × 10-12 µm which are translucent, two-septate, and slightly darkened. The growth of mycelia, conidia formation and conidial germination of the conidial of the pathogen can occur at all pH level for except 2.35-2.95 with optimal conditions for mycelial growth, formation of conidia and germination of conidia were maximum at the pH of 4-6, 4.60-6.45 and 4.60 – 5.45 respectively [13]. Another study determined that mycelial growth was at maximum at a pH of 6.5 and least at 3.5 [14].

3. LIFECYCLE AND DEVELOPMENT

The fungus infects all the aboveground parts of rice plants at all its growth and developmental stages as a result of its polycyclic nature [15-16]. *Magnaporthe oryzae* lifestyle is hemibiotrophic at the initial stage of biotrophic that later advanced to necrotrophic stage. The stage at which the plant cell is attacked and suppressed is called biotrophic stage while necrotrophic stage is the stage when cells die. The source of the pathogen inoculum varies. It may come from the rice plant residues or debris, rice seeds, soil, working equipments or on other alternate hosts. The fungus mycelia can survive on plant residues, plant living tissue and the asexual spores called conidia can survive for more than one season in both tropical and subtropical regions. The mycelia of the fungus can survive on rice straws for more than three years at the temperature range of 18-32ºC and conidia develop when getting moistened. Upon the arrival of the conidia on the rice plant, the sticky mucilage produced during hydration from an apex compartment of conidium tip helps it to stick to a plant surface [17,18]. The conidia germination will begin whenever the humidity level on the host plant is favorable. The emergence of germ tubes from conidium's tapering end grows and spreads on the host plant surface. The germ tube developed and form appressorium afterward. This appressorium formed from germ tube contains melanin and chitin molecules in the host plant cell wall [18,19]. Turgor pressure imposed by glycerol presence leads to the penetration peg which produced by appressoria into the host cuticle and cell wall. The peg produced from the appressoria penetrates the cuticle and cell wall of the host plant as a result of glycerol that is present and this enhances turgor pressure for easy penetration [20].

The appressoria enter into the rice through the plant's stomata. The development of lesions on the rice plant part is a result of the expansion of the *Magnaporthe oryzae* hyphae in tissue of the plant. The hyphae invade and colonized the plasma membrane and epidermal cells of the host plant. The hyphae do not only feeds on the tissue by obtaining nutrients from the plant tissue and spread to various parts through plasmodesmata but also produce effector molecules to attack the host cells immunity and initiate infection [21]. *Magnaporthe oryzae* replicates within a very short period by mitosis, nuclear migration, and death of conidia which mark the beginning of infection [22,23]. The manifestation of the pathogen occurs within 3 to 4 days after infection [18].

4. EPIDEMIOLOGY

Conidiophores produced from the autophagic cell death of conidia are transmitted to other plant tissues or nearby by plants by wind, working tools, water splash or plant contact start a new infection cycle [24,25].The pathogen conidia can spread within 230 meters from its source when the environment is favorable; high relative humidity with winds of 3.5 m s-1 or more [26]. Airborne *Magnaporthe oryzae* conidia exist all-year-round and are responsible for epidemics occurrence throughout the year [27,28]. Longer period of leaves dampness, relative humidity of about 92-96% and the air temperature around 25-28°C were environmental factors that favor spores growth and lesion development [29,30]. However, reports from several researches have indicated that a high dosage of nitrogen supply favors heavy *Magnaporthe oryzae* infection.

5. SYMPTOMS

The rice blast pathogen infects all the aerial parts of the rice plant at various growth and developmental phases like leaf, leaf sheath, internodes, nodes, internodes, neck, panicle [31]. The severity of infection depends on the environmental conditions prevailing the area, the age of the host plant and the degree of resistance of the rice plant. The leaves are the most affected plant part by the pathogen. The foliar lesions reduce the leaf area that should be available for photosynthesis thereby reduces grain yield in return. Severe infection at the early stage of the plant tiller may destroy it. Whenever the pathogen attacked the neck and node of the rice plant, the plant tissues will be disorganized and this inhibits the movement of water and nutrient that ensure grain filling for good yield. Neck and node blast result to early panicles maturity that brings about yield losses through grain shedding and the quality of the harvested grain is reduced [10]. Early neck infection of the plant brings about inhibition of grain filling while partial grain filling will occur in late infection [32]. Partial to complete sterility may occur when the last node is severely infected [33]. Node and panicle blast have been described as the greatest destructive disease of rice at the reproductive and ripening phase [34]. The infected panicle usually gets broken and falls off; even the inflorescence may break off as a result of rotten node that could can no longer support it again. Seeds fail to develop when the pedicles become infected, a condition called seed blanking.

6. MANAGEMENT PRACTICES

The use of resistant varieties, cultural practices, chemical and biological control, nutritional management and biotechnological techniques can be adopted or integrated for the management of blast disease. In developing nations like Nigeria, the use of resistant varieties is considered the best option for the best poor resource farmers in managing this problem.

6.1 Cultural Practices

The adoption of good agronomic practices cannot eradicate the disease but it will reduce its incidence greatly with little energy and money. Farm sanitation reduces the spread of the diseases. Burning of diseased straw, residual plant needs to be burnt to prevent the inoculum to past to the next cropping season. The use of seeds treated with fungicides will reduce the inoculum load on the seeds. Drought stress affects rice than any other cereals because the crop cannot regulate its transpirational water loss and this accelerates the rate of rice blast infection. It has been suggested the use of flooding as a water management strategy to minimize the rate of the pathogen infection unlike plants experiencing drought [35]. Upland rice is more susceptible than rice grown in flooded areas due to the water presence, hence flooding in upland rice reduces the disease severity because of the anaerobic condition [36].

Early planting is recommended during the rainy season to reduce the rate of infection. Late planting of susceptible varieties results in severe infection in the crop, leading to plant death [37]. Adopting the zero-tillage system reduces the incidence of rice blast compared to the normal conventional cropping methods [38]. Excessive application of nitrogenous fertilizer should be avoided as it increases the growth of the disease.

6.2 Chemical Control

Chemical control in rice blast management simply means the use of synthetic products to control the pathogens. Research has shown that some fungicides like tricyclazole, iprobenfos, benomyl, isoprothiolane, diclocymet, edifenphos, probenazole, carpropamid, and metominostrobin, and antibiotics such as blasticidin and kasugamycin are effective against the blast disease. The disease severity, forecast or incidence history in an area will dictate the type and dosage of fungicide to be used, the methods of application to adopt and the time and frequency of its application. Research findings reported the use of Tricyclazole 22% and Hexaconazole 3% SC three times at weekly intervals at the beginning of the booting stage. This combination and application time gave maximum grain yield with the lowest disease incidence. Hence, this is recommended [39].

6.3 Biological Control

The use of biological agents in controlling pathogen is referred to as biological control. The use of *Chaetomiumcochliodes* is effective in controlling rice blast diseases. The use *Chaetomiumcochliodes* spore to coated rice seeds reduces the rate of early blast. Researchers studies revealed that *Bacillus subtillis* strain B-332, 1Pe2, 2R37, 1Re14 and *Streptomyces sindenius* isolate 263 antagonize rice blast disease caused by *Magnaporthe. oryzae* [40]. The use of a virulent isolates of *M. oryzae* for mass vaccination was found to reduce the incidence of rice blast [41]. Most of the illiterate and poor resource farmers don't have access to these isolates and they cannot handle them. A safe commercialization of these isolates is warranted and agricultural extension officers should train the farmer on the proper usage and handling of these isolates.

6.4 Botanical Control

Some botanicals exhibits some antifungal properties. The phytochemicals in these botanicals inhibits the activities of *Magnaporthe oryzae. Atalantia monophylla* and *Plumbagorosea* can control blast disease up to 82.22% and 70.57% respectively; *Atalantia monophylla* contains 4.8 mg/g of phenol and flavonoids (24.5 mg/g)[42]. Aqueous extracts from *Aloe vera, Allium sativum, Annona muricata, Azadirachta indica, Bidens pilosa, Camellia sinensis, Chrysanthemum coccineum*, processed *Coffee arabica, Datura stramonium, Nicotiana tabacum* and *Zingiber officinalis* control rice blast disease in-vitro and in-vitro [43]. Processed *Coffee Arabica* at 10% and 25% (v/v) had the highest (81.12%) and (89.40%) inhibitory effect respectively. All these botanicals showed an inhibitory effect on the rice blast pathogen and do not have any phytotoxic effect, so these are recommended for their antifungal properties for better rice blast disease management [43].

6.5 Nutrition Management

The biological, chemical and physical property of the soil where the crop is grown dictates the ability of the plant to resist diseases [44]. A good knowledge of plant nutrition management about plant-diseases relationships is essential for a high-yield production system. Soils with adequate essential nutrients characterized with high organic matter coupled with high biological activities are an indication of good soil fertility, in return the soil will boost the immune system of the plant thereby reducing the rate of infection [44]. Nitrogen is one of the essential nutrients for plant growth and development. This nutrient, nitrogen is inherently low in most of Nigeria soil and in the tropics at large [45] and this is a limiting factor for high yield. Farmers are aware of this and they tend to supplement the low soil nitrogen with inorganic nitrogen fertilizer.

A high dosage of nitrogen above the recommended dosage increases the increase the incidence blast lesion [46], while low nitrogen dosage increases blast lesion due to weak rice plants with insufficient defenses against diseases [47]. However, a non-essential element, silicon, increases resistance to pests, diseases and drought especially in grass families. Low silicon uptake in rice plant increases the rate of blast susceptibility [48] while high silicon accumulation in rice tissue reduces rice blast incidences [49].

6.6 The Use of Resistance Varieties

The use of varieties that are resistant to rice blast disease offer a better control strategies. It is less expensive and not laborious compare to other methods. Although, developing a rice blast disease resistance varieties is time-consuming and difficult for plant breeders because the fungus can evolve and mutate to overcome resistance genes [50,51]. Blast-resistant rice genotypes have been developed with the use of marker-assisted backcrossing [41,52]. The use of resistant varieties is eco-friendly and economically viable. Comprehensive screening of rice landrace varieties with potential for blast resistance is highly essential. Local varieties that are resistant to the pathogen are the sources of introgression of new resistance genes into some designated rice varieties in a breeding program. Although many researchers pointed out to varieties of rice like IR36, IR64, Moroberekan, OrysicaL lanos5, CO39, Digu, Tetep, Suweon 365, Pongsu Seribu 1, sonarbangla1, and Pongsu Seribu 2 which are found to be resistance to blast attack [53-57]. These varieties are not readily available to rice growers in developing and under-developed parts of the world.

6.7 Forecasting Systems

The use of computer programming models for forecasting disease outbreaks is gaining popularity. A new machine for learning technique prediction approach that is sometimes used for developing weather-based prediction models *in Magnaporthe oryzae* [58]. These prediction models help to estimates the disease likelihood and guess the level of the outbreak, and this forecast will help in preparing for the approaches to use in its control.

6.8 Biotechnological Approaches

The use of biotechnological and molecular approaches is novel in blast disease management. The availability of the rice plant and *Magnaporthe oryzae* genome sequences have paved ways for future researches with promising results in developing rice cultivars that are resistant to blast pathogen. Insertion and deletion of genes using biotechnological methods for developing resistant varieties is another opportunity scientists are exploring. The use of Nano molecules through nanotechnology has been very effective. The use of cisgenesis, a form of genetic alteration as been used to achieved a blast resistance in rice varieties [59]. However, all these are available in developed countries.

6.9 Integrated Management

This involves the use of two or more disease control methods for effective management. The use of natural products such as botanical plant extract, microbial antagonists for controlling rice blast diseases is eco-friendly, safe for humans, and other organisms [60]. The use of fungicides in blast control is also effective but is costly and inappropriate usage should be avoided. All control measures should be adopted by the farmers before considering chemical control.

7. CONCLUSION

A good understanding of rice blast epidemics management is highly essential to bridge the gap between global rice production and the ever-increasing rice demand. Combining different control management approaches will minimize the rice blast incidence and increase yield to sustain food security especially with the use of resistance variety. Where rice blast disease resistance is not available to rice growers, combating the fungal should commence before planting right from seeds treatment to having a clean field free of the pathogen inoculum. The use of chemical treatment should be the last option for rice growers in combating rice blast disease not only for its high cost but considering its health implications on humans and the ecosystem at large. Excessive use of nitrogen fertilizer should be avoided; excessive purchase of nitrogen fertilizer should be replaced with silicon-containing formulae. As neck and panicle blast have more negative effects on grain yield, all attempts should be made to minimize the infection before the booting stage for better yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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