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Integrated management of false smut disease in rice: A review

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Abstract
False smut disease of rice caused by *Ustilaginoidea virens* (Cooke), has become a major concern not only in India but also in almost all rice-producing areas in the world. The pathogen completely converts the grains into spore balls, unfit for consumption and seed production. The fungus overwinters in the soil by means of sclerotia and chlamydospores. Sclerotia produce ascospores, which are primary source of infection to rice plants, whereas secondary infection may come from air-borne chlamydospores. Intensive method of rice cultivation with use of heavy nitrogenous fertilizers resulted into the severe form of disease. Currently the disease is managed only by prophylactic sprays of selected fungicides. Besides Prediction or forecasting Proper management strategies with non- chemical means are needed to be framed to control the disease. Progress in achieving the resistance varieties and management of false smut needs more emphasis. This review summarizes the present status of the disease and progress in the field of its integrated management by resistant varieties, exploration of resistance genes, chemical and non-chemical means of control including the use of bio-control agents.

Keywords: False smut disease, *Ustilaginoidea virens*, Chlamydospores, IDM, Resistance varieties, Fungicides, Biological control

Introduction
Rice continues to be the most important food crop for more than half of the world's population. India is the largest rice growing country with an area of around 44 m ha and production of more than 100 million tonnes (www.fas.usda.gov/psdonline). It is grown in almost all the states of India and plays a major role in country's food security and provides livelihood for about 70 per cent of the population. (Diwakar. 2009) [13]. Rice crop is attacked by number of fungal, bacterial and viral diseases. Among them, diseases caused by fungal pathogens are the major causes of crop damage. False smut has become one of the emerging fungal grain diseases of rice. False smut pathogen, *Ustilaginoidea virens* (Cooke) Takahashi (teleomorph *Villosiclava virens*Tanaka) on rice was first reported and described by Cooke in 1878 from Thirunelveli district of Tamil Nadu in India (Cooke. 1878) [12]. Tanaka *et al*. (2008) [33] suggested the *Villosiclava virens* as teleomorph of *U. virens.* Subsequently, the disease was reported from more than 40 countries including almost all rice growing regions of the world viz., India, Philippines, Myanmar, Colombia, Peru, Bengladesh, Mauritious, Nigeria, Burma, Sri Lanka, Fijji, Africa (Biswas., 2001) [6], USA (Rush *et al.*, 2000) [29] and Egypt (Atia., 2004). Disease incidence of 10-20% and 5-85% respectively has been reported from Punjab and Tamil Nadu in India on different rice cultivars (Ladhalakshmi *et al*., 2012) [21]. The disease causes reduction in the quality and quantity of rice grains and also affects the germination vigour of the infected seedlings (Sanghera *et al*., 2012). Pathogen on infected grains produces antimitotic cyclic peptides, ustiloxin from its chlamydospores, poisonous to both humans and animals (Nakamura *et al*., 1994; Koiso *et al*., 1994) [26,]. The symptom appears only after flowering, by then the fungus infects the individual grains of the panicle (Atia., 2004) [4].The pathogen over winters in soil by means of sclerotia and chlamydospores. Sclerotia produce ascospores, which are primary source of infection to rice plants, whereas secondary infection

may come from air-borne chlamydospores (Ashizawa *et al*., 2010) [2]. The most economical and effective strategy to manage false smut is breeding of durable resistance varieties (Cartwright *et al*., 2000; Wang *et al*., 2010) [10, 17]. Rice cultivars exhibit significant differences in quantitative resistance still no variety is yet to have complete resistance to *U. virens* (Biswas., 2001; Li *et al*., 2008; Huang *et al*., 2015) [6, 24, 17]. Management of false smut has been achieved through cultural, biological and chemical control. The efficacy of several fungicides to manage false smut has also been reported by various workers (Pannu *et al*., 2010; Mohiddin *et al*., 2012) [19]. This review summarizes the present status of the disease and progress in the field of its integrated management using resistant varieties, exploration of resistance genes, chemical and non-chemical means of control including the use of bio-control agents.

Rice False Smut Disease

Symptoms

Rice False Smut Disease is also known as Green smut and considered as Lakshmi disease, because it was always found associated with bumper harvest. The false smut pathogen, *Ustilaginoidea virens*, infects rice at the time of panicle development and affects the young ovary of the individual spikelet transforming it into large, yellow to velvety green balls (smut balls) and the symptoms produced are visible from milky stage onwards. Initially, the smut balls are small in size and remain confined between glumes. They gradually enlarge and enclose the floral parts. The individual grain get converted into yellowish smut ball then changes to yellowish orange to green, olive green and greenish black on maturity. Powdery dark green spores are released when smut balls burst open (Biswas, 2001; Atia., 2004) [6, 4]. If the infection occurs before fertilization most of the glumes remain sterile without any visible sign of infection. Typical large, velvety, green smut balls develop when infection occurs after fertilization. The fructifications replacing the grains represent the conidial, pseudosclerotial and sclerotial stages of the pathogen. The pseudosclerotia (green smut balls) consists of mycelial tissue and spore masses, remnants of anthers and portions of palea and lemna. In general only few grains are affected in a panicle but the number may rise up to 100 in case of severe disease incidence (Ladhalakshmi *et al*. 2012) [21].

Disease Management

Host Plant Resistance: A large number of rice varieties have been reported to be resistant or tolerant by various workers based on their reaction under natural condition in fields (Dodan and Ram Singh.1996) [15]. However artificial screening procedures are not dependable. Research on rice false smut resistance screening and molecular mechanism of false smut resistance is not sufficient (Zhang *et al*., 2014) [23]. Phenotyping of rice cultivars for false smut is based on scoring system as per the standard evaluation system (SES) scale of IRRI (2002). Singh and Singh (2005) [32] evaluated and screened 27 rice genotypes resistant to false smut from 98 rice germplasm. Four rice genotypes were screened by Mohiddin *et al*. (2012) [25], HRI 119 being the most resistant genotype with low disease incidence. Screening of 186 rice hybrids to false smut resistance was done by Yan *et al*. (2014) [37], who identified few hybrids with low disease incidence. Screening of 125 rice genotypes by artificial inoculation of false smut Kaur *et al*. (2015) [19] identified nine hybrids namely Hybrids VNR-211, GK-5025, HRI-140, IRH-74, PRSH-9018, KPH-467, RH-10428, 27P64 and KRH-4 which shown complete resistance to rice false smut.

Cultural Methods

Early transplanted rice had higher disease incidence when compared to late planting (Chhottaray. 1991; Dodan and Ram Singh., 1995) [11, 14] while Sanne (1980) [30] reported that false smut can be avoided by early sowing. Conservation tillage, continuous rice cropping and moderate nitrogen fertility rates reduced false smut disease in susceptible cultivars (Brooks *et al*., 2009) [8]. To escape severe damage, sowing date and heading period could be planned in such a way that flowering should not coincide with rainy period. Use of sclerotic free seeds for sowing and cleaning of bunds may help the farmers to reduce the initial occurrence of the disease. In respect of cultivation practices, furrow irrigated rice cultivation system recorded less disease severity compared to flooded fields. The mechanism behind is the reduction on the survival period of chlamydospores in soil and occurrence of physiological changes in the host plant in response to shift of rice cultivation from anaerobic to aerobic growing conditions (Brooks *et al*., 2010) [9].

Chemical Control

The control of rice false smut disease is mostly dependent on chemical fungicides. Copper fungicides Viz., Copper oxychloride, copper hydroxide proved highly effective (Dodan and Ram Singh., 1997) [16]. Liang *et al*., 2014 [23] found the control efficiency of 91.92 % by spraying 2.5 % Wenquning, a suspension of *Bacillus subtilis* in solution of validamycin with 4.5 Litre/ha at 6 days before heading. The time of application of fungicides are also important to control the disease. Ashizawa *et al*. (2012) [3] reported the infection of *U. virens* from booting to flowering stage. Bagga and Kaur (2006) [5] evaluated and reported significant reduction in false smut incidence by spraying with fujione 40 EC (0.1, 0.2 and 0.3%) and Carbenadazim 50% WP (0.1 %) at the booting stage. Treatment with Copper Oxy Chloride (Blitox) 50 WP (0.3%) and Propiconazole (tilt) 25 EC (0.1%) were found as the most effective. Tasuda *et al.* (2006) found the application of fungicide Simeconazole under submerged condition at 3 weeks before rice heading as more effective against rice false smut disease.

Evaluation of fungicides triûoxystrobin 25%+ tebuconazole 50% and propiconazole 25 EC in vitro and in vivo condition showed 100% inhibition to growth of fungal mycelium. Application of prochloraz + carbendazim followed by chlorothalonil was effective in controlling the false smut of rice (Mohiddin *et al*., 2012) [25]. Raji *et al*. (2016) [28] reported that propiconazole 25EC (0.1 %) recorded lowest disease severity than other treatments, followed by trifloxistrobin + tebuconazole 75 WG when sprayed at booting or 50% panicle emergence. Higher yields were obtained by spraying of Propiconazole 25 EC at booting stage and also trifloxystrobin + tebuconazole 75 WG at booting.

Control by Plant Products

Plant products such as leaf extracts and plant oils could also be used to control rice false smut. Raji *et al*. (2016) [28] studied plant extracts under in vitro against rice false smut pathogen which was considerably inhibited by bulb extract of garlic (*Allium sativum*), rhizome extract of turmeric (*Curcuma longa*), leaf extracts of lantana (*Lantana camara*) and bael (*Aegle marmelos*), whereas plant oils of lemon grass (*Cymbopogon flexuous*) cinnamon (*Cinnamomum*

zeylanicum), and palmarosa (*Cymbopogon martinii*) have completely inhibited the growth of *U. virens*.

Biocontrol of Rice False Smut Disease

Bacillus subtilis (Liu *et al*., 2007) [22] was reported to be effectively against the disease. Kannahi *et al*. (2016) [18] studied the antagonistic potential of 9 isolates of *Trichoderma viride*, *Trichoderma virens*, *Trichoderma harzianum* and *Trichoderma reesei* obtained from rice rhizosphere under in vitro condition and reported that all the isolates of Trichoderma have showed antagonistic activity against *U. virens* but among them isolate of *T. viride* showed maximum antagonistic potential. Andargie *et al*., 2017 [1] reported first time *Antennariella placitae* as a potential fungal endophyte effective in reducing the negative effects of rice false smut fungus (*Ustilaginoidea virens*) both in vitro and in vivo condition.

Conclusion

Because of intensive methods of rice cultivation, overdependence on chemical fertilizers, changes in varietal profile and climatic condition, false smut disease of rice has emerged as one of the major threats to rice cultivation in India. The potential of the disease to cause yield losses up to 50 per cent in terms of both quantity and quality indicates its potential of threat. The work on host plant resistance has not progressed much due to paucity of knowledge in culturing of the fungus and artificial induction of the disease. With the increasing importance of the disease, the research on the searching of resistant genes and management of false smut disease has to be intensified. Cultivation of resistant varieties is the best method to control disease. As culturing of the fungus will have been standardized and artificial induction of the disease would be reported, major focus shall be needed on evaluation of large pool of germplasm and use of the resistant germplasm in the breeding program. Detailed studies on the occurrence of disease in hybrids vis- a- vis varieties are also needed. Another area of work which needs attention is prediction or forecasting of the disease occurrence for better management of the disease. Focus is also required for overwintering of the pathogen and spread of the disease especially in Indian plains where the disease has become an endemic. However, few varieties showing false smut resistance have been reported till date, management through fungicides only has been found effective in managing false smut of rice at present. The disease is presently managed only by prophylactic sprays of selected fungicides. Among the fungicides tested, triazole group of fungicides have been reported to control false smut effectively. Other effective non-chemical means of control including the use of bio-control agents or plant products need to be explored.

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