Eco-friendly Management of False Smut (*Ustilaginoidea virens*) of Rice

Aman Kumar Gupta¹*, Jiwan Paudel², Dipa Yadav¹, Devansh Kumar², Ramu Yadav² and Shrvan Kumar³

¹IAS, Banaras Hindu University, Varanasi-221005, (U.P.), India
²Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur 231001, UP, India
³Department of Mycology and Plant Pathology, IAS, Banaras Hindu University, Varanasi-221 005, (U.P.), India

*Corresponding author

**A B S T R A C T**

False smut of rice caused by *Ustilaginoidea virens*, perfect sexual stage *Villosiclava virens*. *Ustilaginoidea virens* belongs Division – Ascomycota, Class – Sordariomycetes, Order – Hypocreales, Family – Incertaesedis. The yield losses due to RFS 1 -75% is measured. The symptoms are visible only after flowering when the fungus transforms into globose structures or yellowed carbonaceous masses of individual grains of panicle. These masses are dusty representing more than twice in diameter of normal grain. At early stage, development of fungus areshow yellow and then changed in dark green or almost black color, and explode releasing the spores of the fungal causal agent. The pathogen survives both in seed and also in collateral host. The fungus by the means of sclerotia and chlamydospores overwinters in soil. Ascospores produce by sclerotiaare primary source of infection to rice plants, whereas air-borne chlamydospores may cause secondary infection. The seed should be treated through biological control agents like *Trichoderma viride*, *Trichoderma virens*, *Trichoderma harzianum* and *Trichoderma reesei* against *Ustilaginoidea virens* find more effective to control diseases. Growing of resistant hybrids variety like VNR-211, GK-5025, HRI-140, IRH-74, PRSH-9018, KPH-467, RH-10428, 27P64 and KRH-4. By spraying of 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 to control false smut.

**Keywords**

False smut of Rice, *Ustilaginoidea*, Integrated, Bio control agents, Chemical control

**Article Info**

Accepted: 04 October 2019
Available Online: 10 November 2019

**Introduction**

False smut or green smut is a common disease of rice caused by *Ustilaginoidea virens* in rice growing regions of India. Epidemics of false smut disease of rice were reported in Tamil Nadu in India and later in many countries of world (Singh and Pophaly, 2010). False smut of rice caused by a fungal pathogen, *Ustilaginoidea virens* (Cooke) Takahashi, is a common grain disease of rice around the world. The disease was first reported from
Tinnevelli in Tamil Nadu, India by Cooke in 1878 (Ou, 1972).

In recent years, it has emerged as the most devastating grain disease in the majority of rice growing areas of the world. In India, the disease has been observed in severe form since 2001 in major rice growing states, viz., Haryana, Punjab, Uttar Pradesh, Uttarakhand, Tamil Nadu, Karnataka, Andhra Pradesh, Bihar, Jharkhand, Gujarat, Maharashtra, Jammu & Kashmir and Puducherry (Dodan and Singh, 1996 and Mandhare et al., 2008). Antimitotic cyclic peptides, ustiloxin from its chlamydospores are produced by pathogen on infected grains, poisonous to both humans and animals (Nakamura et al., 1994; Koiso et al., 1994). Ascospores produce by sclerotiaare primary source of infection to rice plants, whereas air-borne chlamydospores may cause secondary infection (Ashizawa et al., 2010). The pathogen survives as dormant structures such as sporeballs, chlamydospores, sclerotia etc. in soil, stubbles of the crop and also in collateral hosts (Singh and Dube, 1976; Yashoda and Anahosur (2000). The collateral hosts aid in the off-season active survival of the pathogen. The reported collateral hosts of U. virens include Oryza officinalis, Digitaria marginata, Panicum trypheron, Echinochloa crusgalli, Imperata cylindrical etc. (Rao and Reddy, 1955; Shetty and Shetty, 1985; Shetty and Shetty, 1987; Atia, 2004). There have been many reports of severe outbreaks of RFS since 2001 in many rice-growing provinces of China, such as Liaoning, Hubei, Sichuan, and Anhui; the yield loss ranged from 20 to 50% indifferent areas and varied with rice varieties. In 2005, the occurrence area of RFS disease was approximately 330,000 ha and a third of the panicles in Sichuan were affected (Lu et al., 2009).

RFS having causing significant yield losses globally has become an important disease of rice. The disease reduces yield, affects grain quality and imposes health hazards significantly in all rice producing areas. (Tanaka et al., 2008), Infection by the pathogen transforms individual grains of infected panicles into initially orange, becoming yellowish green or greenish black at maturity (Ou, 1972; Lee and Gunnell, 1992).

**Economic importance**

Upadhyay and Singh (2013) reported that yield loss due to RFS disease from many rice growing areas ranges from 1 to 75%. (Pannu et al., 2010) also reported losses up to 44 per cent in Punjab. In Uttar Pradesh, yield losses up to 44 percent were observed by (Singh and Dube, 1978). In some rice growing districts of Bihar, 15-50 percent losses occurs due to false smut of rice when comes as medium to severe form (Laha et al., 2013). In Bangladesh 10-15% of annual production loss was due to false smut disease (Latif et al., 2007). The disease causes both quantitative and qualitative losses. The losses in grain yield occur due to chaffiness, reduction in test weight and sterility of the spikelets neighbouring smut balls. The yield losses have been estimated to vary between 0.2 - 49% in different states of the country. (URL-1).

**Host Range**

The alternate host through which pathogen survivesare, barnyard grass (Echinochloa crusgalli), Imperata cylindrical, and common rice weed Digitaria marginata. (URL-1) During infection, U. virens produces mycotoxins such as Ustilotoxins A and B which contaminate rice seeds and straw, man and livestock are also harmed by these mycotoxins(Shan et al., 2013). The fungus attacks some of the weed species that commonly occur in rice fields and may also serve as sources of inoculums (Atia, 2004). The pathogen survives as dormant structures such as sporeballs, chlamydospores, sclerotia...
etc. in soil, stubbles of the crop and also in collateral hosts (Singh and Dube, 1976; Yashoda and Anahosur, 2000).

**Taxonomic Position**

*U. virens*, the causal agent of false smut, belongs to the division Ascomycota, subdivision Pezizomycotina, and class Sordariomycetes (Nguyen et al., 2012). *Ustilaginoidea virens* (Cooke) Takah., (1896) Synonyms *Tilletia oryzae* Pat., (1887) *Sphacelotheca virens* Omori, (1896) *Ustilagovirens* Cooke, (1878) *Ustilaginoidea oryzae* (Pat.) Bref., (1895) (URL-4).

**Morphology of Pathogen**

In order to study the detailed cultural characteristics of the pathogen, 5 mm mycelial discs were collected from ten days old culture of *U. virens* and inoculated at the center of PSA plates under aseptic cultural condition in three replicates (27 ± 2°C temp). (Manu et al., 2017). The fungus produces ustilotoxin, a phytotoxin and a mycotoxin thus contaminating rice products (Koiso et al., 1992 and Li et al., 1995). Smut balls are initially yellow in colour and are covered by a membrane, later the membrane bursts and the colour changes to yellowish green and finally greenish black (Gulzar et al., 2012). Chlamydospores formed in the masses of spores are spherical to elliptical, warty, of olive color, and 3 to 5 × 4 to 6 μm. Colonies on PDA developed in approximately 14–15 days. (Quintana et al., 2012). 10–15 days after rice anthesis the balls begin to appear. Balls consist of white hyphae, at the beginning, which later forms thick yellow, loose outer layer of chlamydospores in summer and early autumn, and an olive to black, hard outer layer in late autumn. With higher and lower temperature differences between day and night- especially in later autumn- sclerotia often form on the colony surfaces (Zhang et al., 2013).

**Symptom**

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).

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) consist of mycelial tissue and spore masses, remnants of anthers and portions of palea and lemma. 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). The symptoms are visible only after flowering when the fungus transforms the individual grains of the panicle into globose structures or yellowed carbonaceous masses. These masses are dusty representing more than twice the diameter of normal grain and at early development are yellow and then acquire dark green or almost black color, and explode releasing the spores of the fungal causal agent (Quintana et al., 2012). The disease has been reported on the male inflorescence of *Zea*
mays and on wild species of Oryza (Mulder and Holliday, 1971).

**Diseases cycle**

Fungus *Ustilaginoidea virens* insight the disease. *U. virens* produces both sexual (sclerotia) and asexual (chlamydospores) stages in its life cycle. Sclerotia are the major source of primary inoculum. In nature, over wintered sclerotia germinate and produce ascospores and coincides with the anthesis of early sown rice crop. Ascospores feed on the floral parts and initiate infection. Air-borne chlamydospores play an important role in the secondary infection, which is a major part of disease cycle (URL-1). Various disease incidents and severity significantly varies between seasons and locations. Seed germination in smut-infected samples was 72.4% which is 21.45 per cent lower than the non - smutted samples (92.20%) (Gulzar and Sanghera et al., 2012).

During the surveys common graminaceous grasses and sedges in the rice fields like *Echinochloa colona, Echinochloa crus-galli, Digitaria longifolia, Leersia hexandra, Fimbristylis millaceae, Cyperus rotundus*, weedy rice etc. were observed for the presence of false smut disease. Observations were made on any other modes of active survival as well. (Rashmi et al., 2016).

The fungus overwinters as sclerotia in the soil. They germinate and produce spores that infect the grain. The disease first appears as a large gray to brownish green fruiting structure covered by a thin membrane that replaces one or more grains of the mature panicle (URL-3). Ascospores produce by sclerotia are primary source of infection to rice plants, whereas air-borne chlamydospores may cause secondary infection (Ashizawa et al., 2010). The RFS pathogen grows and contaminates the infected plant tissues, including the stamen and filament. Thus, this is regarded as the plant stamen-filament disease (Tang et al., 2013).

**Epidemiology**

False smut (*Ustilaginoidea virens*) was observed during Oct II and III week and that coincided with average temperature 27.42º C, relative humidity of 83 per cent and rainfall of 12.1 mm (Vakiti et al., 2017). High relative humidity (>90%), temperature between 25 and 30ºC and rainy days at the time of flowering are the favourable environmental factors for the disease infection, as mentioned by (Atia2004). Fungi can reproduce by selfing or outcrossing. In heterothallic ascomycetes such as *Tuber melanosporum* Vittad (Rubini et al., 2011). The maximum disease severity and incidence were occurred at temperature range of 32-24ºC, relative humidity (88-74%), rainfall (6.67-6.66 mm) and sunshine hrs (6.20-6.29 hrs) both in case of variety Sabourardhajal and 25th June sown crop whereas, minimum disease incidence and disease severity occurred when temperature and relative humidity was same but their sunshine hrs and rainfall was lower than both Sabourardhajal and 25th June sown crop in case of Sahbhagi variety and 15th July sowing (Priya et al., 2017).

**Integrated diseases management**

Prediction or forecasting Proper management strategies with non-chemical means are needed to be framed to control the disease. More emphasis should be given for achieving the resistance varieties and management of false smut needs. 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 (Sanjeet et al., 2018). Management of the disease has been achieved through cultural,
biological and chemical control. (Pannuet et al., 2010; Mohiddin et al., 2012) reported the effectiveness of various fungicide against false smut. According to farmers, inadequate management of these diseases resulted in poor production in crops (Nelson et al., 2001). The strategic management of the disease may be directed to the specific areas of the fields where there is a history of the disease through manipulating genotypes and transplanting time (Sarker et al., 2017).

**Resistant cultivars**

Research on rice false smut resistance screening and molecular mechanism of false smut resistance is not sufficient (Zhang et al., 2014). 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) evaluated and screened 27 rice genotypes resistant to false smut from 98-rice germplasm (Yan et al., 2014). Screened 186 rice hybrids to false smut resistance was done who identified few hybrids with low disease incidence. Screening of 125 rice genotypes by artificial inoculation of false smut (Kaur et al., 2015) 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 control**

Weeding and insecticides application were done at appropriate time for best management practices (Priya et al., 2017). Early transplanted rice had higher disease incidence when compared to late planting (Chhottaray, 1991; Dodan and Ram Singh, 1995).

Conservation tillage, continuous rice cropping and moderate nitrogen fertility rates reduced false smut disease in susceptible cultivars (Brooks et al., 2009). 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 (Sanjeet et al., 2018). 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). The management of the rice seedling and adult plants were the same as the conventional method except for an extra application of 75 kg/hm2 urea at the beginning of rice booting stage (Zhang et al., 2014). Cultural practices like bunds and fields cleaning reduce the incidence as the disease has been reported on some of the weeds.

**Biological control**

Biological control should done by Trichoderma viride, Trichoderma virens, Trichoderma harzianum and Trichoderma reesei against Ustilaginoidea virens (Kannahi et al., 2016). Raji et al., (2016) 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 (Aeglemarmelos), whereas plant oils of lemon grass (Cymbopogon flexuous) cinnamon (Cinnamomum zeylanicum), and palmarosa (Cymbopogon martini) have completely inhibited the growth of U. virens. Bacillus subtilis (Liu et al., 2007) was found effective against the fungus.

Andargie et al., (2017) reported first time Antennariella placitae effective against rice false smut (Ustilaginoidea virens) both in vitro and in vivo condition.
Chemical control

(Liang et al., 2014) found the control efficiency of 91.92% by spraying 2.5% Wenquning, a solution of validamycin suspension of Bacillus subtilis® at 4.5 Litre/ha at 6 days before heading. Bagga and Kaur (2006) evaluated and reported significant reduction in false smut incidence by spraying with Carbenadazim 50% WP (0.1%) and fujione 40 EC (0.1, 0.2 and 0.3%) at the booting stage. Treatment with Propiconazole (tilt) 25 EC (0.1%) and Copper Oxy Chloride (Blitox) 50 WP (0.3%) were found as the most effective. Application of prochloraz + carbendazim followed by chlorothalonil was effective in controlling the false smut of rice (Mohiddin et al., 2012). Spraying of chlorothalonil 75 WP (Kavach) @ 2 ml/l or Propiconazole 25 EC (Tilt or Result) during flowering reduce the disease incidence (URL-1). The fungicides evaluated exhibited 100% inhibition on the growth of U. virens eight days after inoculation in vitro in Nordox (copper fungicide), Mancozan super (Mancozeb 640 g/kg + Metalaxyl 80 g/kg), Suncozeb (80% WP Mancozeb) and Sidalco defender (435 g/l copper oxychloride), however, after 23 days only Nordox inhibited mycelium growth (Daniel et al., 2017). (Researchers) reported that two sprays of 50% propiconazole EC at 300 g a.i. ha⁻¹ and of 10% difenoconazole GR at 225 g a.i. ha⁻¹, exhibited the best control of rice false smut. Treated seed with trifloxystrobin (Trilex 2000), and propiconazole plus trifloxystrobin (Stratego) were also effective in reducing false smut with foliar application at the heading stage (X Zhou et al., 2012).

References

Andargie M, Congyi Z, Yun Y, Li J.). Identification and evaluation of potential bio control fungal endophytes against Ustilaginoidea virens on rice plants. World J Micrbiol Biotechnol. 2017; 33(6): 120-125.

Ashizawa T, Takahashi M, Moriwaki J, Hirayae K. Quantification of the rice false smut pathogen U. virens from soil in Japan using real-time PCR. European J Plant Pathol. 2010; 128: 221-2.

Atia MMM, Rice false smut (Ustilaginoidea virens) in Egypt. Journal of Plant Disease and Protection. 2004; 111: 71-82.

Atia MMM. Rice false smut (Ustilaginoidea virens) in Egypt. Journal of plant disease protection. 2004; 14:71-82.

Atia, M MM. 2004.Rice false smut (Ustilaginoidea virens) in Egypt. J. Pl. Dis. Prot., 111:71-82.

Bagga PS, Kaur S. Evaluation of fungicides for controlling false smut (Ustilaginoidea virens) of rice. J Indian Phytopath.2006; 59:115-117.

Biswa A. False smut disease of rice: a review. Environment and Ecology. 2001; 19:67-83.

Brooks SA, Anders MM, Yeater KM. Effect of cultural management practices on the severity of false smut and kernel smut of rice. Plant Dis. 2009; 93:1202-1208.

Brooks SA, Anders MM, Yeater KM. Effect of furrow irrigation on the severity of false smut in susceptible rice varieties. Plant Dis. 2010; 94: 570-574.

Chhottaray PK. Doctor of Philosophy Thesis, Orissa University of Agriculture and Technology, Bhubaneswar, Orissa, 1991, 175.

Cooke, M. C. 1878. Some extra-European fungi. Grevillea. 7: 13-15.

Daniel Dokie Tokpah, Charles Kwoseh, Eric Saye Tokpah and David Kolleh (2017). Rice false smut and its management in major rice growing areas in Ashanti region of Ghana.

Dodan DS, Ram Singh. Effect of planting tim on the incidence of blast and false smut of rice in Haryana. Indian Phytopathol. 1995; 48:185-186.

Dodan, D. S. and Singh, S. R. 1996. False smut
of rice. Present status. Agric. Review. 17: 227-240.

Gulzar S. Sanghera, M A Ahanger, S C Kashyap, Z A Bhat, A G Rather and G A Parray SKUAST-Kashmir, Mountain Research Centre for Field Crops, Khudwani, Anantnag192102, J&K, India.

Gulzar S. Sanghera, M AAhanger, S C Kashyap, Z A Bhat, A G Rather and G A Parray SKUAST-Kashmir, Mountain Research Centre for Field Crops, Khudwani, Anantnag, 192102, J&K, India.

https://doi.org/10.20546/ijcmas.2017.607.077

Kannahi, M., Dhivya, S. and Senthilkumar, R. (2016) Biological Control on Rice False Smut Disease using Trichoderma Species. DOI: http://dx.doi.org/10.18782/2320-7051.2237

Kaur Y, Lore JS, Pannu PPS. Evaluation of rice genotypes for resistance against false smut. Plant Dis. Res. 2015; 30(1):46-49.

Koiso, Y., Natori, M. and Iwasaki, S. (1992). Ustilotoxin: a phytotoxin and a mycotoxin from false smut of rice panicles. Tetrahedron Letter, 33 : 4157-4160.

Ladhalakshmi D, Laha GS, Singh R, Karthikeyan A, Mangrauthia SK, Sundaram RM. Isolation and characterization of Ustilaginoidea virens and survey of false smut disease of rice in India. Phytoparasitica. 2012; 40: 171-176.

Laha GS, Prasad MS, Krishnaveni D, Ladhalakshmi D, Prakasam V. Production oriented survey. Directorate of Rice Research Rajendranagar. Hyderabad. 2013; 45-48.

Latif, M A, M S Kabir, N R Sharma and M A Hossain. 2007. Dhaner Pacti Prodhan Rogar Somonitto Babosthapona (Integrated management of five main diseases of rice). Bangladesh Rice Research Institute (BRRI), Gazipur 1701, Bangladesh (Bangla). pp. 1-2.

Lee, F.N., Gunnell, P.S. 1992. False smut Compendium of rice diseases St Paul: American Phytopathol. Soc., Pp. 28.

Li YS, Zhu Z, Zhang YD, Zhao L, Wang CL. Genetic analysis of rice false smut resistance using major gene plus polygene mixed genetic model. ActaAgron Sin, (in Chinese with English abstract). 2008; 34(10):1728-1733.

Li, Y., Koiso, Y., Kobayashi, H, Hashimoto, Y. and Iwasaki, S. (1995). Ustilotoxin, new antimitotic cyclic peptides: Interaction with procine brain tublin. Biochemical Pharmcol., 49 :1367-1372.

Liang Y, Zhang X, Li D, Huang F, Hu P, Peng Y. Integrated approach to control false smut in hybrid rice in Sichuan Province, China. Rice Sci. 2014; 21:354-360.

Liang Y, Zhang X, Li D, Huang F, Hu P, Peng Y. Integrated approach to control false smut in hybrid rice in Sichuan Province, China. Rice Sci. 2014; 21:354-360.

Lu DH, Yang XQ, Mao JH, Ye HL, et al., (2009). Characterising the pathogenicity diversity of Ustilaginoidea virens in hybrid rice in China. J. Plant Pathol. 91: 443-451.

M MSarker, A H M MHaque, B Nessa, M U Salam, M M Islam, and A Muqit (2017) Status of Rice False Smut Disease in Natore District of Bangladesh. Bangladesh Rice J. 20 (2) : 31-37, 2016

Mandhane, V. K., Gawade, S. P., Game, B. C. and Padule, D. N. 2008.Prevalence and incidence of bunt and false smut in paddy (Oryza sativa L.) seeds in Maharashtra. Agrl. Sci. Dig. 28: 292-294.

Manu, D.G., S.S. Pramoda, A. Ramanathan, S. Ramchander, S. Manonmani, P. Jeyaprakash and Robin, S. 2017. Isolation, Characterization and Pathogenesis of Ustilaginoidea virens Causing False Smut Disease in Rice (Oryza sativa L.). Int.J.Curr.Microbiol.App.Sci. 6(7): 632-640.

Mohiddin FA, Bhat FA, Gupta V, Gupta D, Kalha CS. Integrated disease management of false smut of rice caused
by *Ustilaginoidea virens*. Trends in Biosciences. 2012; 5(4):301-302.

Mohiddin FA, Bhat FA, Gupta V, Gupta D, Kalha CS. Integrated disease management of false smut of rice caused by *Ustilaginoidea virens*. Trends in Biosciences. 2012; 5(4):301-302.

Mulder, J. L. and Holliday, P. 1971. *Ustilaginoidea virens*. [Descriptions of Fungi and Bacteria]. IMI-Descriptions-of- Fungi-and-Bacteria. (30), Wallingford, UK: CAB International, Sheet 299.

Nakamura K, Izumiyama N, Ohtsubo K, Koiso Y, Iwasaki S. Lupinosis like lesions in mice caused by ustiloxin produced by *Ustilaginoidea virens* a morphological study. Natural toxins. 1994; 2:22-28.

Nelson R, Christopher M, Ricardo O, Oscar O, Marjon F, Tenorio J, Vinh NV (2001). Working with resource-poor farmers to manage plant diseases. The Am. Phytopathol. Soc. 85(7):1-12.

Nguyen, Liem Thi Thanh, "False Smut of Rice: Histological Analysis of Infection" (2012). Theses and Dissertations. 652. http://scholarworks.uark.edu/etd/652

Ou, S.H. 1972. Rice diseases Commonwealth Mycological Institute Kew.

Pannu PPS, Third TS, Goswami S, Standardization of technique for artificial creation of false smut of rice and its management. Indian Phytopathology. 2010; 63:234-35

Pannu PPS, Third TS, Goswami S. Standardization technique for artificial creation of false smut of rice and its management. Indian Phytopathol. 2010; 63:234-235.

PriyaBhargava, Amarendra Kumar and Sanjeev Kumar (2017) Epidemiological studies of false smut disease of rice (*Ustilaginoidea virens*) in Bihar.

Quintana L, Gutiérrez S, Maidana M and Morinigo K (2016) Rice false smut (*Ustilaginoidea virens* (Cooke) Takah.) in Paraguay. Tropical Plant Research 3(3): 704–705.

Raji P, Sumiya KV, Renjisha K, Dhanya S, Narayanankutty MC. Evaluation of fungicides against false smut of rice caused by *Ustilaginoidea virens*. International Journal of Applied and Natural Sciences. 2016; 5(2):77-82.

Rao, G. P. and Reddy, V. T. C. 1955. Occurrence of *Ustilaginoidea virens* (Cke.) Tak. On Oryza officinalis Wall. Indian Phytopath., 8: 72-73.

Rashmi C R, Gokulapalan C, Girija V K, Surendran M (2016) On the off season survival of *Ustilaginoidea virens*, the pathogen causing false smut of rice in Kerala.

Rubini A, Belfiori B, Riccioni C, Tisserant E, Arcioni S, Martin F, Paolocci F (2011) Isolation and characterization of MAT genes in the symbiotic ascomycete *Tuber melanosporum*. New Phytologist 189:710-722.

Sanjeet Kumar, SeemaKumari and Bidya Shankar Sinha (2018) Integrated management of false smut disease in rice: A review P-ISSN: 2349–8528 E-ISSN: 2321–4902 IJCS 2018; SP4: 48-51

Shan T, Sun W, Wang X, Fu X, Sun W, Zhou L (2013). Purification of ustiloxins A and B from rice false smut balls by macroporous resins. Molecules 18:8181-8199.

Shetty, S. A. and Shetty, H. S. 1985.A hitherto unrecorded collateral host of *Ustilaginoidea virens* (CKE) TAK. Curr. Sci., 54: 646-647.

Singh AK, Pophaly DJ, An unusual rice false smut epidemic reported in Raigarh District, Chattisgarh. International Rice Research Notes. 2010; 35:1-3.

Singh AK, Singh RN. Screening for resistance to false smut (*Ustilaginoidea virens* Takahashi) of rice (*Oryza sativa* L.). Indian J Genet. 2005; 65:49-50.

Singh RA, Dube KS, Assessment of loss in seven rice cultivars due to false smut. Indian Phytopathology. 1978; 31: 186-188.
Singh, R. A. and Dube, K. S. 1976. Occurrence of true sclerotia in *Claviceps oryzae-sativae* the causal organism of false smut of rice. Curr. Sci., 45: 772-773.

Singh, R. A. and Dube, K. S. 1976. Occurrence of true sclerotia in *Claviceps oryzae-sativae* the causal organism of false smut of rice. Curr. Sci., 45: 772-773.

Tanaka E, Ashizawa T, Sonoda R, Tanaka C (2008). *Villosiclava virens* gen.nov.comb.nov., the teleomorph of *Ustilaginoidea virens*, the causal agent of rice false smut. Mycotaxon 106:491-501.

Tang Y, Jin J, Hu D, Yong M, Xu Y, He L (2013). Elucidation of the infection process of *Ustilaginoidea virens* (teleomorph: *Villosiclava virens*) in rice spikelets pp. 1-8.

Upadhyay A, Singh RV (2013). Yield loss assessment in rice due to false smut. Ann. Plant Soil Res. 15:173-174.

Vakiti, Devendhar, Bhale, Usha, Teja, T. Ramya, Bhale, M.S. and Koutu, G.K. (2017). Utilization and identification of rice genetic stock against false smut disease under agro conditions of Jabalpur (M.P.). Agric. Update, 12(TECHSEAR-1): 79-82; DOI: 10.15740/HAS/AU/12.TECHSEAR(1)2017/79-82.

X Zhou. “Field evaluation of fungicides for management of rice false smut and kernel smut”. Texas A&M University System, Agri Life Research, Beaumont, TX, USA (2012).

Y Chen., et al., “Frequency distribution of sensitivity of *Ustilaginoidea virens* to four EBI fungicides, prochloraz, difenoconazole, propiconazole and tebuconazole, and their efficacy in controlling rice false smut in Anhui Province of China”. Phytoparasitica 41 (2013): 277-284.

Yan L, Xue Mei Z, De Qiang L, Fu H, Pei Sing H, ung Liang P. Integrated approach to control false smut in hybrid rice in Sichuan province, China. Rice Science. 2014; 21(4): 354-360.

Yashoda, H. and Anahosur, K. H. 2000. Survival, perpetuation and lifecycle of *Claviceps oryzae-sativae*, causal agent of false smut of rice in Karnataka. Indian Phytopath., 53: 61-64.

Yashoda, H. and Anahosur, K. H. 2000. Survival, perpetuation and lifecycle of *Claviceps oryzae-sativae*, causal agent of false smut of rice in Karnataka. Indian Phytopath., 53: 61-64.

Zhang, T, Y Jiang, J Huang and W Dong. 2013. Complete genome sequence of a putative novel victorivirus from *Ustilaginoidea virens*. Archv. Virol. 158: 1403-1406.

How to cite this article:

Aman Kumar Gupta, Jiwan Paudel, Dipak Yadav, Devansh Kumar, Ramu Yadav and Shravan Kumar. 2019. Eco-friendly Management of False Smut (*Ustilaginoidea virens*) of Rice. *Int.J.Curr.Microbiol.App.Sci.* 8(11): 388-396. doi: [https://doi.org/10.20546/ijcmas.2019.811.049](https://doi.org/10.20546/ijcmas.2019.811.049)