“STUDIES ON FALSE SMUT OF RICE IN CHHATTISGARH REGION”

M.Sc. (Ag.) THESIS

by

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DEPARTMENT OF PLANT PATHOLOGY

COLLEGE OF AGRICULTURE

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"STUDIES ON FALSE SMUT OF RICE IN CHHATTISGARH REGION"

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Anish Muraleedharan

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VITA

The author was born on 14th April 1980 in Kollam (Dist.), of Kerala. He completed his Xth class from the Board of Public Exams, Kerala securing 86 per cent marks and Pre degree (10+2) from the University of Kerala securing 74.8 per cent marks. He pursued his career-related studies in the field of agriculture by joining the Raja Balwant Singh College, Agra for under graduate programme. Throughout his graduation programme, he stood first in the university securing 74.4per cent marks and will be awarded gold medal in the next convocation. He joined the Indira Gandhi Agricultural University for his P.G programme in Plant Pathology as an ICAR nominee. The author kept a good academic record during his P.G programme securing an O.G.P.A of 9.03/10.00 (90.3%) and stood first in his department and second in the whole university and is presently submitting the thesis in the partial fulfillment of the requirements for the degree of Master of Science in Agriculture.

The author actively participated in various quiz competitions during his school period and has won several prizes and scholarships. He kept keen interest in sports and has represented his university twice in table tennis championships during his U.G. programme.

CERTIFICATE – I

This is to certify that the thesis entitled "**STUDIES ON FALSE SMUT OF RICE IN CHHATTISGARH REGION"** submitted in partial fulfilment of the requirements for the degree of **"Master of Science in Agriculture"** of the Indira Gandhi Agricultural University, Raipur, is a record of the bonafide research work carried out by **ANISH MURALEEDHARAN** under my guidance and supervision. The subject of the thesis has been approved by Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published/ published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

Date: **Chairman**
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CERTIFICATE - II

This is to certify that the thesis entitled **"STUDIES ON FALSE SMUT OF RICE IN CHHATTISGARH REGION"** submitted by **ANISH MURALEEDHARAN** to the Indira Gandhi Agricultural University, Raipur in partial fulfilment of the requirements for the degree of **M.Sc. (Ag.)** in the **Department of Plant Pathology** has been approved by the Student's Advisory Committee after oral examination in collaboration with the external examiner.

Date: **EXTERNAL EXAMINER**

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Director of Instructions _____

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"This frail vessel thou emptiest again and again, and fillest it ever with fresh life. This little flute of a reed thou hast carried over hills and dales, and hast breathed through it melodies eternally new…. Thy infinite gifts come to me only on those very small hands of mine. Ages pass, and still thou pourest, and still there is room to fill".

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CHAPTER-I

INTRODUCTION

Globally, rice is one of the most important cereal crops followed by wheat. From the day of civilization, the rice genus *Oryza* has fed more people over a longer period than any other crop. It is grown extensively in the tropical and sub tropical regions of the world. About 90 per cent of the rice grown in the world is produced and consumed in Asia. It is India's staple food contributing to about 45 per cent of the total annual cereal production. Almost in all the states of the country, it is cultivated during wet (*kharif*) season and also as a double crop in few states during *rabi* and summer seasons. The bulk of the Asia population, the urban poor, land less rural population and the marginal farmer spends more than half of their income on rice, being the dominant staple food (Singh, 2000).

India has the largest acreage under rice cultivation covering about 44.8 million ha (FAO, 2001), which is about 35.5 per cent of the total area under food grain production (126 m ha). The current food grain production is estimated to 220 million tones with the rice basket contribution of 78.6 million tones (The Hindu, 2004).

The total geographic area of Chhattisgarh is 13.6 m ha and out of this, the net sown area is 4.82 m ha. This small state owning the sobriquet, 'Rice bowl of India' has got 3.7 m ha area under rice cultivation with the production of 3.635 million tones (Status Report, I.G.K.V., Raipur, 2003).

Rice production plays a pivotal role in our food grain security, consistently holding the key for the sustained food sufficiency in the country. Rice production in India increased from less than 46 million tones in 1965 to more than to double in 1999 (FAO, 2001). The quantum jump in rice production came from the introduction of dwarf high yielding varieties during the late sixties. However, a plateau in rice yield is now being experienced. It is estimated that the rice demand in 2010 will be 100 million tones and in 2025 will be 140 million tones (The Hindu, 2004). This challenge can be met only from increased productivity under the stress conditions such as depleting resources availability.

The rice productivity level is almost attaining a plateauing level. Therefore, there is an urgent need to look for an alternative strategy for breaking yield barriers. Rice research has to be geared up to surmount the technological challenges in breaking the genetic yield barriers, improving input use efficiency and developing environmentally acceptable strategies for alleviating losses due to pests and diseases. Only vertical rise in productivity may be the answer for matching the expected future demands. Increase in productivity largely depends on proper crop management and protection from insect pest and diseases.

Rice is under constant threat due to large number of biotic stresses accounting for production in the developed states of the country and due to both biotic and abiotic constraints in the poor states of the country. Introduction of high yielding dwarf varieties, with an associated change in the

rice growing technology such as, higher plant population, higher doses of fertilizers and increase in irrigation, there occurred a gradual shift in the disease pattern of a locality. A number of minor diseases have attained the status of major importance. One such disease, which has gained attention far and wide, is the 'False Smut Disease' of rice.

False smut or orange smut or green smut as the disease is popularly known is incited by the pathogen *Ustilaginoidea virens* (Cke.) Tak whose teleomorph being *Claviceps oryzae sativae* (Hashioka). The fungus transforms individual grains of the panicle into greenish spore balls of velvety appearance. The spore balls are small at first and grow gradually to a size of two inches or more in diameter. They are smooth and yellow and are covered by a membrane. Later, the membrane bursts and the colour of the ball becomes orange/yellow. When cut open, the ball is white in the centre with three outer layers (Sciumbato and Street, 2000).

As far as the disease cycle is concerned, the fungus survives in the winter by means of sclerotia and chlamydospores. Primary infection is by ascospores produced by the sclerotia. Secondary infection is by airborne chlamydospores. Substantial losses due to this disease have been reported by several workers. The main reason for losses being incited is that the fungus attacks the panicles. About 15-20 per cent losses have been reported by different workers from different provinces (Singh, 1998).

Looking at the low productivity of rice in this region, where the farming community almost depends on this important food crop, there is an

urgent need to address the biotic stress like ‘false smut’. Very meagre information is available about this disease particularly as the extent of yield losses it causes and about infection and impact. Therefore the present research studies entitled

“Studies on false smut of rice in Chhattisgarh region” was taken up with the below mentioned objectives:

1. Per cent incidence of the false smut in different cultivars (Early, Medium, late and hybrids).
2. Extent of number of grain infection in panicle of susceptible variety.
3. Conditions favouring the false smut.
4. Structure of chlamydospores. Variations in the chlamydospores (if any).
5. Role of chlamydospores in infection.
6. Seed health testing for the false smut infection from seed lots.
7. Yield loss assessment.

CHAPTER -II

REVIEW OF LITERATURE

False smut of rice caused by *Ustilaginiodea virens* was earlier considered as a minor disease. Recently, this disease has become a serious problem in most of the rice growing countries and especially in Indian sub continent. As it was considered earlier not a serious disease, only few workers contributed to the literature on this problem. In the present review, all the available information pertinent to the problem was reviewed and presented as below:

2.1 Occurrence

False smut caused by *Ustilaginoidea virens* has become a major and serious problem in some of the hybrid rice growing areas and continuous cropping with high inputs.

This disease false smut or green smut as it has also referred to be, was first reported in Tirunelveli, Tamil Nadu, India, in 1878. This disease was also reported from different states of the country. From Andhra Pradesh (Rao and Reddy, 1955), Madhya Pradesh (Sharma and Joshi, 1975), Uttar Pradesh (Singh *et al*., 1987), Orissa (Narain, 1992) and Andaman and Nicobar islands (Ansari *et al*., 1988). Under congenial conditions, it is known to cause considerable losses.

The false smut presence was referred from most parts of the rice growing countries including Philippines, Peru, Burma (Revilla, 1955), Fiji

(Morwood, 1956), China, Columbia, Japan, Taiwan, Thailand, Indonesia, Malaysia, Brazil, Sri Lanka, Sudan, Venezuela, Vietnam and Zambia (Neira, 1969; Hashioka, 1971; Gangopadhyay, 1983 and Mew and Misra, 1994), Australia, Italy (Anonymous, 1977), Bangladesh (Li *et al*., 1986), Pakistan (Akhtar and Sarwar, 1986), Southern Guinea zone of Nigeria (Imolehin, 1989) and from Iran (Izadyar *et al*., 1998).

Yearly fluctuation patterns of the occurrence of false smut in paddy fields in Ibaraki Prefecture, Japan was reported by Irino and Komori (1995).

From United States the false smut was first reported in 1997, Arkansas, USA covering twenty countries with severe losses in northeast Arkansas, attaining an epidemic form (Cartwright *et al*., 1999).

2.2 Symptoms

Typical large, velvety, green smut balls (pseudomorphs) were reported to develop when infection occurs after fertilization (Kulkarni and Moniz, 1975).

Ou (1985) reported that the fungus transformed the individual grains of the panicle into greenish spore balls of velvety appearance. He found that the spore balls were small at first and were visible in between the glumes, growing gradually to reach 1cm or more in diameter and enclosed the floral parts. The spore balls were found to be slightly flattened, smooth and yellow and were covered by a thin membrane. In the later stages, the membrane bursts and the colour of the ball became orange and later yellowish green or greenish black.

Reddy and Reddy (1992) also described that the pathogen grows in the ovary and transforms it into large, yellowish and velvety green balls, which become greatly enlarged at later stage. They found that the spore balls were covered by a membrane in the early stages, which bursts with further growth and the loose velvety pseudomorphs become visible. The surface of the ball was found to crack at this stage.

The fungus transforms individual grains of the panicle in to greenish spore balls of a velvety appearance. The spore balls are smooth and yellow and are covered with a membrane. The membrane bursts and the colour of the ball becomes orange (Sciumbato and Street, 2000).

2.3 Causal organism

Cooke (1878) for the first time described the fungus causing false smut, considered it to be a true smut and described the pathogen as *Ustilago virens* and his inference was based up on the sample specimen collected from India. The false smut samples sent from Japan were identified and attributed due to *Tilletia oryzae* (Patouillard, 1887). Takahashi (1896) studied the fungus causing false smut disease of rice and named it as *Ustilaginoidea virens* (Cke.) Tak whose teleomorph being *Claviceps oryzae sativae* (Hashioka, 1971).

Much confusion prevailed on the nomenclature of this fungus. But as the anamorph stage is correctly identified as *Ustilaginoidea virens* (Cke.) Tak, most of the workers adopted this name (Ou, 1985).

Ahuja and Payak (1988) suggested that *Ustilaginoidea virens* (Cke.) Tak is a valid name and *Claviceps oryzae sativae* Hashioka should be treated as a synonym of *Ustilaginoidea virens.*

2.4 Per cent incidence, per cent grain infection and disease severity index.

Revilla (1955) observed more than 25 per cent infected tillers on different varieties from Tuber Valley, Peru.

Singh and Dube (1978) surveyed the per cent of smutted tillers and smutted balls per panicle on seven promising rice cultivars. They found a maximum of 70 per cent incidence in the cultivar Ratna and a minimum of 1 per cent in Sona. They recorded 23 per cent smutted balls in the variety Ratna. Disease severity index was also found to be high in Ratna (1610.0) and least in Sona (2.87).

Patel *et al*. (1984) surveyed the occurrence and severity of the rice diseases at different crop stages in three districts of South Gujarat and found false smut to occur in a moderate rate.

Per cent infected tillers, per cent smutted balls and disease severity index were reported on twenty two rice cultivars (Ansari *et al*., 1988). They obtained 100 per cent infected tillers from the varieties Vikas, DR-447-20 and DR-253-2 where as they recorded the minimum incidence in cultivars MTU-6861 (2.0%) and RP-1854-566-1-1-1 (2.86%). Per cent smutted balls were high in the cultivars DR-447-20 (6.0) and in UPR-239-151-1 (5.7). Least per cent smutted balls were reported from UPRI-80-120 (0.53) and CR-310-10

(0.54). Their studies revealed highest severity index (600.0) in the cultivar DR-447-20.

Xia (1989) found several flower infections to occur more in hybrid rice. He reported one such infection to be caused by *Ustilaginiodea virens.* He found that the extended angle of glume to be wider in hybrid rice and also the flowering phase to be longer in hybrid rice which resulted in more infection. He reported more incidence of false smut in hybrid rice lines.

In Andhra Pradesh, Muralidharan *et al.* (1990) noticed ten false smut balls per panicle during their survey. Singh (1990) reported the disease to be sporadic in the field and also in an individual ear, only a few grains are affected. He found that in severe cases, many smut balls may aggregate together.

Dhindsa *et al*. (1991) recorded the false smut disease of rice in five rice cultivars (PR 103, PR 106, PR 108, PR 109 and Jaya) at Gurdaspur, Punjab and reported maximum incidence of 30.67 per cent in the cultivar PR 109. Maximum per cent smutted balls were also recorded on PR 109 (4.73).

Baruah *et al*. (1992) reported the severity of false smut on thirteen cultivars. The incidence of false smut on the cultivars was recorded between 7.2-52.1 per cent. Per cent smutted balls were reported to be in the range 3.7-18.4. High disease severity index was also recorded from the cultivars with the cultivar Sialsali showing a severity index of 956.8. They also reported disease index to be in the range of 26.6-958.6.

In a comparison of three cultivars, RR 8585, IET 12355 and IR 39323 conducted by Chib *et al*. (1992) for the per cent smutted balls, it was found that the cultivar IET 12355 exhibited the maximum per cent of smutted balls (13.4). They reported the maximum per cent of smutted balls in the cultivars RR 8585 and IR39323 to be 9.6 and 12.2 respectively.

Reddy and Reddy (1992) listed the false smut incidence in different states of the country on large number of varieties through the compilation of the production oriented survey reports. False smut disease was found to be of major importance with good infection severity in various cultures in Zamboanga City, Philippines (Pedrozo and Yumol, 1994).

Rice cultivars, Taraori Basmati and CR-333-6-1 were planted at 5, 15 days interval, starting from 10th June in Karnal, Haryana. The crop planted on June 10th had the least incidence of false smut. False smut was maximum in CR-333-6-1 with 36.9 per cent incidence and 0.6 per cent smutted balls (Dodan and Ram Singh, 1995).

Cartwright *et al*. (2000) evaluated a total of 161 rice lines in three separate disease nurseries at the Pine Tree Experiment Station for false smut disease. The false smut nursery relied on natural inoculum. They found 108 lines of rice infected by false smut, with 28 lines having greater than 10 smut balls on any panicle. They observed a highest of 28 smutted balls in one panicle from the line RU9901121.

Biswas (2001) observed false smut on 21 out of 47 rice selections in shallow water at the National Screening Nursery at Rice Research Station,

Chinsurah, West Bengal. A maximum false smut infection (27%) was found to occur in the cultivar IET 15730.

A survey on the disease incidence at rice fields in eight inland provinces of Korean Republic was carried out in the year 2000, showing that the disease occurred at 104 (7.5%) out of the 1152 rice fields examined, ranging from 1.5 to 13.7 per cent in provincial average (Shim *et al*., 2001). They reported two cultivars Gaumnambyeo and Namchumbyeo severely affected by false smut having more than 20 per cent of disease incidence.

Ahonsi and Adeoti (2002) assessed the incidence and severity of false smut caused by *Ustilaginoidea virens* on upland rice in eight rice producing locations in Edo State, Nigeria. Their studies revealed that incidence and severity of the disease differed significantly by the time of survey and location and a maximum of 53.8 per cent mean incidence and 29 per cent mean severity was recorded on different rice cultivars.

Cheng *et al*. (2003) obtained a significant correlation between disease index and per cent infected panicles and between disease index and average number of spore balls per panicle.

2.5 Conditions favouring the False smut

Higher relative humidity (> 90%), lower minimum and maximum temperature and cloudy days, along with little precipitation during flowering period are congenial for disease development (Govinda Rao and Raju, 1955; Singh, 1974).

Manibhushan Rao (1964) found that the weather during the flowering period of the varieties had some influence on the incidence of the false smut disease. He also found that the number of rainy days influenced the disease development more than the amount of rainfall.

Singh (1974) indicated that the disease was favoured by the prevalence of lower minimum and maximum temperature, high relative humidity (92% and above) before and during early flowering and lower relative humidity later in the flowering period. His studies revealed that precipitation and cloudy days influence temperature and relative humidity, which determined the incidence. Considerable losses were reported by the false smut pathogen under favourable environmental conditions (Singh and Singh, 1985).

Singh *et al*. (1987) found that false smut caused by *Ustilaginoidea virens* has become a very important disease of wet season rice in Uttar Pradesh. They indicated that the meteorological factors of relatively lower temperatures (20^{o}C) and high relative humidity (> 90 %) coupled with well-distributed moderate rainfall during flowering favoured the disease. They also reported that late sowing usually resulted in higher false smut infection. They found a direct correlation between per cent infected tillers and per cent smutted balls per panicle.

Fujita (1989) observed that the disease was favoured by low temperature (15°C) and higher relative humidity (100%) for infection and by a relatively high temperature (25 - 35°C) for appearance of disease symptoms.

Singh *et al*. (1989) found that false smut of rice has become a major disease causing significant losses in yield and its incidence and severity is very erratic. Their experiments for finding the meteorological parameters that affected the false smut development, revealed that a lower maximum (31°C) and minimum (23°C) temperatures and high relative humidity (> 96%), less sunshine hours or cloudy days during the flowering period favoured disease development. They observed that the amount of precipitation at the flowering stage could not be correlated with the severe incidence of the disease. However, it might have indirectly influenced the atmospheric humidity, which favoured the disease development.

Delayed planting with humid weather conditions increased the severity of false smut disease (Agarwal *et al*., 1990). Bhardwaj (1990) did not find any correlation between environmental conditions during flowering period and incidence of false smut.

Reddy and Reddy (1992) reported that the disease is common and serious in temperate and cooler mountainous areas than in hot tropical regions. They found that it occurs more frequently in upland rice areas than in lowland areas, when a spell of wet weather synchronizes with the heading time. They found high moisture to favour the disease development. *Ustilaginoidea virens* caused substantial quantitative and qualitative losses under favourable environmental conditions (Dodan and Ram Singh, 1996).

Bhagat *et al*. (1997) studied the incidence of false smut of rice in relation to meteorological parameters and revealed that a greater infection

occurred at comparatively lower day and night temperatures around 31°C and 25°C with high precipitation resulting in high relative humidity of 90 per cent. They positively correlated the number of cloudy hours during the day with disease development.

Yashoda *et al*. (2000) conducted field experiment during *kharif* seasons of 1996-1997 in Karnataka, to study the effect of weather parameters on incidence of false smut. Their correlation studies indicated that weather parameters during 50 per cent flowering had a significant effect on false smut development in rice. Low maximum temperature (< 31°C), low rainfall (< 5mm), high minimum temperature (19°C) and high relative humidity (> 90%) was found to be favourable for disease development.

Ahonsi and Adeoti (2003) observed that the false smut disease could be severe especially in years with high and extended rainfall causing reduction in grain yield.

2.6 Structure of spore balls and chlamydospores

Chlamydospores are formed on spore balls and are borne laterally on minute sterigmata on radial hyphae and are spherical to elliptical, echinulate, olivaceous, 4-6 x 3-5 μm with epispore 0.3 μm in thickness (Hashioka, 1971).

Ou (1985) reported that spore balls are small at first and are visible in between the glumes, growing gradually to reach 1 cm or more in diameter and enclosing floral parts. He reported that the chlamydospores are formed on the spore balls laterally on minute sterigmata and are spherical to elliptical, warty, olivaceous and measuring 3-5 x 4-6 μm.

Verma and Singh (1988) reported that the chlamydospores differed in the size and spore wall echinulations in different cultures. They reported the size of chlamydospores to be 3- 8 x 3.4 - 6.1 μm. Chlamydospores in old collections were reported to be greenish tinged and warty measuring 4.09-8.08 x 4.09-6.13μm.

Chlamydospores were reported to have smooth surface and measuring 3.5 – 6.0 x 3.5 – 6.8 μm (Wang *et al*., 1997, 1998). They also divided the chlamydospores of false smut into yellow and black types and reported that the surface of both have verrucae which are much more numerous on the black chlamydospores. They found that the black ones do not germinate.

Izadyar *et al*. (1998) found large, black, ball shaped grains on panicles of several rice cultivars. They also noted that only a few grains were usually infected in each panicle, with the other grains smaller than those in healthy panicles. Infected grains were yellowish orange initially, turning olive green and then black. They reported each infected grain contained chlamydospores, measuring 4-7 μm in diameter.

Individual grains of the panicle are transformed in to greenish spores with the spore balls attaining a size of two inches or more in diameter (Sciumbato and Street, 2000).

2.7 Characteristics and germinating ability of the chlamydospores

Hashioka *et al*. (1951) reported that the chlamydospores germinated in water to produce fine germ tube bearing 1-3 conidia. Ou (1985) showed

chlamydospore and mycelial growth to be best at 28°C and least at 12°C; no growth occurs at 36°C. His studies revealed that the optimum pH for the germination of chlamydospores was 6.02-6.72. No growth occurred at pH 2.77 and slight at the pH 9.05.

Tsai *et al*. (1990) recorded the extent of rice infected by *Ustilaginoidea virens* in Taiwan. They observed the majority of smut balls in the middle portion of the panicle. They isolated the pathogen and germination of chlamydospores on sterilized water and water agar was found to be best at 25°C followed by 30°C and 20°C. The optimum pH range was found to be 5.0-8.0 but germination occurred at pH 4.0-9.0. Germination of yellow chlamydospores were reported to be much better (93%) than black chlamydospores (6%).

Sharma and Dave (1992) studied the viability of spores of false smut during storage and the effect of substrate on the germination of spores. They observed that sucrose, glucose and rainwater promoted the germination of spores. They also reported that the germination was pronounced in yellow spores followed by light brown spores and the black spores were not found to germinate.

Chen *et al*. (1994) reported that the optimum temperature for mycelial growth was 28°C. Growth was reported to be slow at 13°C and ceased at 35°C. They observed that various stimulants had no significant effect on the germination of *Ustilaginoidea virens.*

Lu Fan *et al*. (1996) carried out studies on the biological characteristics of the pathogen of rice false smut and observed that the optimum temperature for the germination of chlamydospores was 28°C. The optimum pH values ranged from 5.8 - 6.3. They also found sugar and light to promote germination of chlamydospores. Germinating ability of chlamydospores stored in the field was found to be much greater than that stored indoors.

Wang *et al*. (1997) concluded that when yellow chlamydospores were preserved at 4^{o}C and 25^{o}C, their germinative ability was preserved for 1 year and 80 days respectively. They found an optimum pH of 5.0-8.0 and optimum temperature of 25^{o}C-30^{o}C congenial for the germination of the chlamydospores. Light was also found to promote the germination of the chlamydospores. Singh (1998) reported that hyphal growth and conidial germination could occur at any temperature from 12°C- 34°C, but optimum being 28°C.

2.8 Role of chlamydospores in infection:

Yoshino and Yamamoto (1952) and Ikegami (1960) successfully infected the plants by injecting spore suspension into the leaf sheath cavity at boot stage. They inferred that the infection occurred just before flowering.

Ikegami (1962) inoculated coleoptiles of germinating seeds with chlamydospore suspensions and found that the fungus infected host tissues. Kulkarni and Moniz (1975) successfully inoculated the panicles of flowering rice plants (up to 80%) by applying chlamydospore suspensions of

Ustilaginoidea virens with a camel hair brush both to fertilized and unfertilized ovaries. They found that seed infection by smearing with chlamydospores after surface sterilization was unsuccessful.

Infection occurs in seedling stage when germ tube from conidia penetrate the cuticle of coleoptiles and proceed intercellularly causing systemic infection (Singh, 1983).

Ou (1985) reported that chlamydospores play an important role in the secondary infection of the false smut fungus. Yoshikatsu (1989) reported the successful result of inoculation with injection or spraying the chlamydospore (conidiospore) suspension in field. Chhottaray (1991) reported that spraying of spore suspension at flowering period produced maximum infection.

Yashoda *et al*. (2000) tested various inoculation techniques for *Claviceps oryzae sativae,* like sowing seeds from infected panicles, dipping of roots in chlamydospore suspension prior to planting, sowing of seeds previously soaked in spore suspension, spraying of chlamydospore suspension on seeds before sowing, dusting the inflorescence with yellow smut balls during flowering, spraying of pure culture suspension on inflorescence during flowering stage, injecting the chlamydospore suspension in to flag leaf enclosing the young panicle etc. They obtained the highest of 20 per cent disease development by spraying of pure culture suspension on inflorescence.

Chen *et al*. (2003) inoculated *Ustilaginiodea virens* cultured *in-vitro* to rice plants at the booting stage. They observed that in the artificially inoculated

plants, the per cent infected panicles was upto100 and the number of spore balls per panicle reached 106 and disease index, 85.5.

2.9.1 Seed health testing for the false smut infection from seed lots

Seed health refers primarily to the presence or absence of disease causing organisms of various kinds (ISTA, 1985). Rice seeds as in other crops, serves as a source of perpetuation of the organisms causing diseases of economic importance (Ou, 1985; Mew and Misra, 1994).

Galloway (1936) found that the false smut disease was neither seed borne nor soil borne. The most frequently isolated fungi from rice seed ranged from minor pathogens to major pathogens of economic importance to the rice industry. Minor pathogen's included the false smut fungus (Reddy and Khare, 1977; Zainum and Nik, 1977).

Aruna and Choudhary (1986) surveyed seed mycoflora of paddy from Mysore and reported 34 fungi on 23 rice varieties. One of them was *Ustilaginoidea virens* the incitant of false smut of rice.

Li *et al.* (1986) reported that the reason for initial infection of *Ustilaginoidea virens* must probably be seed borne. Agrawal *et al*. (1989) reported twenty seed borne diseases of rice including the false smut disease caused by *Ustilaginoidea virens.* Kauraw and Mathur (1989) considered false smut as a seed borne systemic disease.

Duhan and Jakhar (2000) tested 609 rice seed samples obtained from various districts of Haryana during 1993-1997 and reported the incidence of

false smut at a constant rate ranging from 0.05 to 0.50 per cent. They found that the trend of false smut incidence was almost constant during 1994-1997.

Hegde and Anahosur (2000) reported that false smut has significantly reduced the per cent seed germination in all rice varieties tested and was maximum in the cultivar Champakali (25.3) and minimum in Rasi (12.9). They also found that the seedlings emerged from seeds of infected panicles had poor seedling vigour.

2.10 Yield loss assessment

Losses in yield due to increased disease severity and sterility of spikelets and smut balls have been reported (Hastell and Diehl, 1929). Rice crop suffered 20 per cent loss in yield due to increased disease severity of false smut in Cauca valley, Colombia (Martinez, 1952).

Singh and Dube (1978) assessed the losses in yield on seven rice cultivars under natural heavy disease pressure. They recorded maximum yield loss on the cultivar Ratna (44.37%) and Bala (24.3%). Least loss in yield was recorded in the cultivar Sona (0.20%). They reported that in addition to the direct loss due to conversion of infected grains in to smut balls, increase in chaffiness and decrease in grain weight were also observed due to the disease. Losses in yield was reported due to increased sterility of spikelets in addition to smutted grains (Li *et al*., 1986).

Ansari *et al*. (1988) evaluated the losses in yield due to false smut in a field experiment using twenty-two promising rice cultures and recorded a maximum loss of 49 per cent in the variety DR 447-20. Least per cent loss in

yield was recorded with RR-1854-566-1-1-1 (0.3). The losses were more in cultures where disease severity index was more.

Dhindsa *et al*. (1991) reported losses ranging from 1.53-16.8 per cent on five different cultivars assessed for yield loss. Losses were computed by individually assessing direct losses due to smut balls.

Baruah *et al*. (1992) reported that the yield of the high yielding variety 'Mahsuri' reduced considerably (9.2%) due to the increase in disease severity index (246.9). Yield loss assessed on the thirteen cultivars ranged between 40.0 -55.2 per cent.

Chib *et al*. (1992) reported a decrease in yield compared to increase in disease incidence and recorded a maximum of 45.7 per cent loss in yield in the variety 1ET 12355 and minimum was recorded in RR 8585 (8.7%).

Ding *et al*. (1997) investigated the yield losses in five intermediate season rice varieties, including three indica and two japonica rice varieties caused by false smut. Their results showed that the rate of milled rice decreased as the number of infected grains increased. Among the five varieties tested, disease severity index of indica varieties was higher than that of japonica rice varieties.

Pannu *et al*. (2002) recorded observations on nine commercially cultivated varieties of rice at two locations during the years 2000 and 2001. They reported severity of false smut in the range of 0.25 – 5.52.and 0.00-3.86 at Gurdaspur and Ludhiana respectively. Significant losses in grain yield were also recorded.

CHAPTER-III

MATERIALS AND METHODS

The materials used in the present investigation and the methods followed are given below.

***In vitro* studies**

All the *in-vitro* studies on *Ustilaginoidea virens* (Cke.) Tak were conducted in the Mycology Lab, Dept. of Plant Pathology, I.G.K.V., Raipur (C.G.).

During the course of investigation, glasswares of Borosil make, plastic plates of Torson make, blotter paper of standard grade and chemicals of standard grade (BDH, Qualigens, Merck etc.) were used in general, unless otherwise mentioned. In addition to the routine equipment, the present studies were also done with the help of standard equipments like Leica compound microscope, Saveer mist chamber, Klenzoids laminar flow, Remi and Calton make BOD incubator etc.

Cleaning and Sterilization of Materials

Whenever required, the glasswares were cleaned with detergent powder, finally washed by cleaning solution and rinsed with tap water or distilled water. The dried glasswares were sterilized in hot air oven at 180^{o}C for two hours. The forceps and other metallic instruments were sterilized by heating over the spirit lamp flame after dipping them in alcohol. Sterilization of the media was done in general by autoclaving at 1.41 kg/cm^{2} for 20 min.

General procedure adopted

The common general procedures adopted during the course of the studies are given below and wherever specific procedures used, they are mentioned separately in the context of the text.

3.1 Field studies

All the field studies were conducted in the Directorate of Research Farm, I.G.K.V., Raipur. (C.G).

3.1.1 Per cent incidence of false smut in different duration cultivars and hybrids

Three different duration groups, *i.e.* early (less than 115 days), medium (115 – 135 days) and late (above 135 days) along with three hybrids were evaluated for the false smut incidence to ascertain that the duration of the cultivars had any influence on the disease. These varieties were selected from the standing crop of different fields of the research farm. The varieties evaluated under early duration were NDR-359, Tulsi, Vandana, MTU-1010, IR-64, IR-42342, R-548-89-6, Parbhani Culture, Nidhi, Patel Super, Aditya, Danteshwari, Kasturi, IR-36, Annada, ADTRH-16, Poornima, Abhaya, HKRH-1094, NDR-97, UDHR-2019, Rasi, PAC-80035, PR-102 and R-371-1. The medium cultivars evaluated were Suldhan, R-1142-604-1-1, Triguna, Shyamala, Suraksha, R-1097-44-3-1, R-1072-360-1-1, R-650-1817, HMT Sona, B.G.380-2, Bamleshwari, Kranti, Pusa Basmati-1, Jaya, R-1055-1629-4-1, Madhuri, R-979-1528-1, Sasyasree, Dodana, BPT-5204, Mahamaya, RAU-3037, Jalpan, Indira-9 and R-6335. Late group comprised of

cultivars like Swarna, Duokang-1, MTU 1001, R.304-34, Phalguna, R-1075-34-1, Karnallocal-B, DRRH-25, Pakshiraj, Parwa, Malagouri, Rajibangla, Gangabarud, Jhilli, Vasumati, NSNI-27, Bagmuchh, Gahuwan, Ambemohar-157, Dokramechha, Badshahbhog, Chinnor, Dubraj, Gopalbhog and Tulsiamrit .The hybrids screened were KHR-2, Sahyadri and Hy.6444. The total number of panicles per hill and the total number of infected panicles per hill were observed for each variety. Ten observations were taken at random from each variety. Per cent incidence of false smut in panicles per hill or per cent infected tillers were calculated by the formula.

$$\text{Per cent infected tillers/panicles} = \frac{\text{Number of infected panicles (tillers) / hill}}{\text{Total number of panicles (tillers) / hill}} \times 100$$

3.1.2 Per cent grain infection (per cent severity of infection).

The per cent grain infection in the above varieties was also recorded. Ten hills earmarked at random for the above observations were also used for recording the per cent grain infection. One panicle from each infected ear marked hill was further selected at random and recorded for the infected and healthy grains. In this manner, observations were recorded from ten panicles.

Per cent grain infection (per cent smutted balls) was calculated using the formula:

$$\text{Per cent grain infection} = \frac{\text{Number of infected grains per panicle}}{\text{Total number of grains per panicle}} \times 100$$

3.1.3 Disease severity index.

Disease severity index was also recorded on all the twenty-five early, medium, late duration varieties and the three hybrid cultivars which were evaluated for per cent infected tillers and per cent smutted balls. The disease severity index was arrived at by multiplying the per cent infected tillers with per cent smutted balls as given by Singh and Dube (1978).

Disease severity index = per cent infected tillers x per cent smutted balls.

Ten observations were maintained for each variety and their averages recorded.

3.2 Meteorological data

The meteorological data (Maximum temperature, minimum temperature, relative humidity, rainfall and rainy days) for the *kharif* season, 2003 were obtained from the Department of Agricultural Meteorology, I.G.K.V., Raipur. The meteorological factors were correlated with the disease severity index.

3.3 Measurement of spore balls.

Fifty spore balls collected at random from the infected samples were measured using vernier calipers. The sum total of main scale reading and the vernier scale reading revealed the length and breadth of the spore balls measured. The average of the fifty observations provided the spore ball dimensions. Prior to this, the least count of vernier calipers was calculated by the method,

10 divisions of vernier scale = 9 divisions of main scale

or

1 division of vernier scale = 9/10 division of main scale

vernier constant = 1- 9/10 division of main scale

= 1/10 division of main scale

1 division of main scale = 1 mm

Therefore,

1/10 division of main scale = 1/10 mm, which is 0.01cm.

(The two jaws of the vernier were put together to determine whether there is zero error or not. The zero of the vernier scale coincided with the zero of the main scale; therefore there was no zero error).

3.4 Study of chlamydospores

3.4.1 Structure of chlamydospores

Spore balls from infected plants were collected and brought to the laboratory. Later on, spore suspension was made in tap water. One drop of this spore suspension was kept on a clean microscopic slide and observed under Leica compound microscope for recording the size. Prior to this, calibration for ocular micrometer reading with that of stage micrometer was standardized using the formula:

S x 10 / 0

Where,

S = Stage micrometer divisions

O = Ocular micrometer divisions

From the spore ball suspensions, fifty microscopic field observations were recorded.

3.4.2 Variations in the chlamydospores

The infected samples were collected from the research farm and two other locations on varieties Aditya, HMT Sona and Swarna (research farm), Hy.6444 (village Tendua) and MTU-1010 (village Beerbara) and were subjected for the studies on chlamydospore variation. Fifty chlamydospores from smut balls of each variety were observed under Leica compound microscope and their dimensions were recorded to see variations if any.

3.4.3 Effect of different pH concentrations on the chlamydospore germination

Chlamydospores were incubated at room temperature under the following pH concentration solutions adjusted to distilled water (4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0 7.5 and 8.0) for 24 hrs. The spore suspensions were then observed under Leica compound microscope for the germination of spores. Observations were recorded from eight microscopic fields for each pH. Per cent germination was calculated using the formula:

$$\text{Per cent germination} = \frac{\text{Number of spores germinated}}{\text{Total spores observed}} \times 100$$

3.4.4 Effect of different glucose concentrations on the chlamydospore germination

Glucose solutions with the concentrations of 0.1, 0.3, 0.5, 0.7, 0.9 and 1.1 per cent were prepared first. Different concentrations (0.1, 0.3, 0.5, 0.7, 0.9 and 1.1 per cent) were prepared by dissolving the glucose (BDH make) in distilled water. Chlamydospore suspension was prepared in these different glucose concentrations and a drop of the suspension was placed on the microscopic slides and incubated at room temperature for 24 hours. The slides

were observed under Leica compound microscope for the germination of spores and observations were recorded from eight different microscopic fields for each glucose concentration. Per cent germination was calculated in the same manner as mentioned elsewhere.

3.4.5 Effect of different temperatures on the chlamydospore germination

Microscopic slides containing chlamydospore suspensions in distilled water were incubated in B.O.D. incubators at 15, 20, 25, 30, 35 and 40°C. Observations were recorded after 24 hours using Leica compound microscope from eight different microscopic fields for each temperature. The per cent germination was calculated in the same manner as mentioned elsewhere.

3.4.6 Effect of field water on the chlamydospore germination.

Chlamydospore suspensions made in sterilized field water were kept on clean microscopic slides and were incubated at room temperature. The microscopic slides were observed under Leica compound microscope after 24 hours for the germination of spores. Observations were recorded from fourteen different microscopic fields. Per cent germination was calculated by the same formula as mentioned elsewhere.

3.4.7 Effect of nutrient solution on the chlamydospore germination

Microscopic slides containing one drop of chlamydospore suspension in nutrient solution, was incubated at room temperature for 24 hours. Prior to this, the nutrient solution was prepared with the following constituents given below, in one litre of water.

Boric acid	–	0.020 gm.
Mangenous sulphate	–	0.016 gm

Zinc sulphate	–	0.003 gm.
Copper sulphate	–	0.001 gm
Molybdic acid	–	0.001 gm.

Observations for the germination of spores were recorded after 24 hours from fourteen different microscopic fields. Per cent germination was calculated in the manner as mentioned elsewhere.

3.5 Growing of Test Plants (Pot studies)

Earthen pots of 9 inches height and diameter 8.5 inches, were filled with 3.5 - 4 kg field soil approximately and was fertilized at N_{100}, P_{50}, K_0 kg/ha rate.

Prior to this, the soil was sterilized by drenching with 4 per cent formalin solution. The soil was then mulched with polythene sheet for 24 hours. After 24 hours, the sheet was removed and the soil was allowed to dry for a day. The unwanted debris was also removed from the soil, prior to the filling in pots. Twenty-one days old seedlings of the cultivar HMT Sona were used for transplanting at the rate of three per each pot. At the time of transplanting soil was made moist. In general Completely Randomized Design was followed during all the pot studies and they were conducted in the 'Saveer Mist Chamber'.

3.5.1 Role of chlamydospores in infection

Chlamydospores were dusted, sprayed with fresh preparation made in sterilized field water and germinated spore suspension was sprayed on to the rice plants (HMT Sona) grown on pots at flowering stage. Ten pots were maintained for the particular treatment and the experiment was repeated five

times. During the entire study the plants were kept under congenial humid conditions in the mist chamber.

3.6 Seed health evaluation

To know the per cent seed infection of the false smut fungus, the seed health evaluation was conducted on six popular and susceptible rice varieties.

3.6.1 Varieties used

Swarna, Mahamaya, HMT Sona, Pusa Basmati-1, MTU-1010 and Indira-9 were the varieties used. They were obtained from the Farm Incharge, Research Farm, I.G.K.V., Raipur. They were properly kept in polythene bags, labelled and stored at room temperature prior to use.

3.6.2 Seed sampling

The seed sample was first thoroughly mixed. The working sample was obtained from the lot and randomly 400 seeds were picked up for the seed health evaluation, following the ISTA Rules (ISTA, 1985).

3.6.3 Seed borne infection

a. Detection of *Ustilaginoidea virens*

The seed samples were subjected for the detection of *Ustilaginoidea virens* by following the seed washing test (Mew and Misra, 1994) and detection under microscope as follows: In a beaker, place the working sample and add water, with or with out a wetting agent, or alcohol. Shake vigorously to remove organisms adhering to the surface. Transfer washings in to centrifuge tubes and centrifuge for about five minutes at low speed (3000-5000 rpm). Decant excess liquid from each centrifuge tube and examine extracted material under a compound microscope for fungal spores.

b. Per cent incidence in infected seed lot

From the total of 400 seed obtained by pooling from the seed lot, individual seed were picked out and imbibed in 0.25 ml distilled water and washed by gently pressing and overturning the seed in cavity glass. The liquid left behind after each washing was thoroughly examined under Leica compound microscope for the presence/absence of *Ustilaginoidea virens.* The per cent incidence or per cent infected seed were recorded by the formula:

$$\text{Per cent infected seed} = \frac{\text{Number of infected seed}}{\text{Total seed observed}} \times 100$$

3.7 Yield loss assessment

Losses in grain yield due to false smut of rice were assessed on ten cultivars under natural heavy disease pressure. The varieties on which observations recorded were Swarna, Sahyadri, IR-64, Aditya, Kranti, Pusa Basmati-1, HMT Sona, MTU-1010, Mahamaya and Rasi. (The assessments were carried out on the varieties present in the research farm, except for Mahamaya and Rasi, which were assessed from the fields of village Pirdha).

Yield loss assessment was done as per the procedure followed by Singh and Dube (1978) and Ansari *et al*. (1988). For the yield loss calculations, the per cent infected tillers were recorded first in the same manner as mentioned elsewhere. Then fifty panicles from unsmutted and smutted tillers were collected separately for each variety to record the total grain weight and per cent smutted balls. The total number of grains and the smut balls were counted from fifty smutted panicles, separately to calculate the per cent smutted balls

(The per cent smutted balls were calculated by the same method as mentioned elsewhere). The total grain weight of fifty smutted panicles (excluding smut-balls) was subtracted from the total grain weight of fifty unsmutted panicles of respective variety to obtain the reduction in weight and the per cent loss in yield was calculated by the formula:

$$\text{Per cent loss in yield} = \frac{100 \text{ x the reduction in grain weight x per cent infected tillers}}{\text{Grain weight of 50 unsmutted panicles x 100}}$$

3.8 Statistical analysis

Wherever required the experimental data were analyzed using RBD and CRD designs.

The skeleton of Anova for CRD is given below:

Source of variation	d.f.	S.S.	M.S.	F ratio
Treatments	n-1	SS_T	V_T	V_T/V_E
Error	N-n	SS_E	V_E	
Total	N-1			

Where,

n = number of treatments

N = Total number experimental units

The skeleton of Anova for RBD is given below:

Source of variation	**d.f.**	**S.S.**	**M.S.**	**F ratio**
Blocks	r-1	SS_B	V_B	V_B/V_E
Treatments	n-1	SS_T	V_T	V_T/V_E
Error	(n-1)(r-1)	SS_E	V_E	
Total	nr-1			

Where,

r = number of replications (blocks)

n = number of treatments

nr = Total number observations

All the statistical analysis were done in the Department of Agricultural Statistics, IGKV, Raipur.

CHAPTER - IV

RESULTS

The present chapter deals with the experimental results obtained during the course of investigation on "Studies on false smut of rice in Chhattisgarh region", wherever required the results were statistically analysed using the analysis of variance technique and the findings are as follows:

4.1 Per cent incidence, per cent grain infection (per cent severity of infection) and disease severity index in different duration cultivars and hybrids

Per cent incidence, per cent severity of infection and apparent severity of the disease for early, medium, late duration and hybrids were studied.

4.1.1 Early duration cultivars (up to 115 days)

Among the twenty five early duration cultivars (Tab 4.1), maximum per cent infected tillers (incidence) were observed in MTU-1010 (56.84) followed by Patel Super (35.36), PAC 80035 (32.34) and Abhaya (29.24) with a significant difference over others *i.e.*, R.371-1, Aditya, PR 102, Nidhi, IR-36, Vandana, NDR-359, IR-64 and R-548- 89-6. The least per cent of infected tillers were recorded in the varieties HKRH – 1094, Annada, Poornima, ADTRH-16 and Parbhani Culture (Fig 4.1).

The early cultivars also showed significant differences for the per cent smutted balls and apparent disease severity index. Highest number of smutted balls was recorded in Rasi (7.08%) followed by MTU-1010 (7.04%). Least per cent of smutted balls were observed in Nidhi, R.371-1, NDR – 359, IR-64, HKRH –1094, IR-36, R-548- 89-6 and ADTRH-16 and were all at par for the per cent smutted balls (Fig 4.2).

Maximum apparent disease severity index calculated as given by Singh and Dube (1978) showed highest severity index in the cultivar MTU-1010 (402.32) followed by Patel Super (166.51), Rasi (141.38) and PAC 80035 (126.21). Varieties PR 102, Danteshwari, Abhaya, UDHR-2019, Aditya, Tulsi, IR-42342, Annada, NDR-97, R-371-1, Vandana, Nidhi, NDR-359, R-548-89-6, IR.64, Poornima, Parbhani Culture, IR-36, HKRH-1094 and ADTRH-16 showed severity indices of 85.43, 78.03, 75.60, 69.84, 65.79, 54.77, 49.91, 42.42, 39.9, 38.13, 33.18, 29.88, 24.58, 23.88, 22.03, 21.35, 20.79, 16.69, 16.09 and 14.26 respectively and were all at par in disease pressure (Fig 4.3).

The experimental findings clearly indicate a relation between the per cent infected tillers, per cent smutted balls and severity index. With the increase in the per cent infected tillers or per cent smutted balls, there was a proportionate increase in the disease severity index among the varieties.

4.1.2 Medium duration cultivars (115-135 days)

Twenty-five medium duration cultivars were evaluated for the per cent infected tillers and per cent smutted balls in each panicle (Tab 4.2). HMT Sona recorded the maximum per cent infected tillers (36.08). Other varieties, which showed significantly high per cent infected tillers were Pusa Basmati-1 (35.74), R-6335 (30.76), Jaya (27.15), Indira-9 (25.89) and RAU-3037 (25.45). The least per cent infected tillers were recorded in Kranti, Madhuri, Bamleshwari and R-1055-1629-4-1 and without significant difference among themselves (Fig 4.4).

There were significant differences in the per cent smutted balls and disease severity index among the medium varieties. However, HMT Sona recorded the maximum per cent smutted balls (6.29) and severity index (208.49) where as Shyamala, Suraksha, R-1142-604-1-1, R-979-1528-1 and Suldhan recorded the least number of smutted balls per panicle (Fig 4.5). Disease severity index was also found to be significantly high in the varieties Pusa Basmati-1 (191.98), Jalpan (154.26), Jaya (143.78) and Indira (101.13) over the varieties Kranti, R-1142-604-1-1, Suldhan and Bamleshwari which recorded the least severity index of infection (Fig 4.6).

4.1.3 Late duration cultivars (135 and more days)

Data (Tab 4.3) indicates that maximum per cent infected tillers were recorded in the variety Jhilli (46.49) followed by Rajibangla (37.47), Malagouri (36.72) and Bagmuchh (36.18). The per cent infected tillers on the cultivar Jhilli was significantly more compared to the other cultivars which

also recorded high per cent incidence. Varieties Parwa, Badshahbhog, Chinnor, Dokramechha, Vasumati, Gahuwan and Pakshiraj also showed high number of infected tillers but were at par with each other in the incidence. Least per cent incidence was recorded in R-304-34, Phalguna, Duokang-1 and MTU-1001 (Fig 4.7).

Maximum per cent smutted balls were observed in the varieties Parwa (11.44), Badshahbhog (9.74) and Pakshiraj (8.88) with a significant difference over Karnallocal B, Phalguna, Gangabarud, NSNI-27, DRRH-25, Gahuwan, Malagouri, Ambemohar 157, MTU-1001, Gopalbhog and R-1075-34.1. However, Tulsiamrit, Swarna, R-304-34 and Duokang-1 recorded least per cent of smutted balls and were at par with each other in the average severity per panicle (Fig 4.8).

Significant differences were observed in the disease severity index among the late duration varieties. Cultivar Parwa recorded the highest severity index (361.78) followed by varieties Badshahbhog, Rajibangla, Jhilli, Pakshiraj, Dubraj and Bagmuchh, which also recorded high disease index with no significant differences among themselves. Least disease severity index was recorded on Swarna, Tulsiamrit, MTU- 1001, R-104-34 and Duokang-1 with indices of 39.68, 34.34, 26.68, 19.45 and 15.86 respectively (Fig 4.9).

4.1.4 Hybrids

Three hybrids KHR.2, Sahyadri and Hy: 6444 were evaluated during the course of study (Table 4.4). Maximum per cent infected tillers (53.57) and maximum disease severity (802.61) was recorded in the hybrid KHR-2. There were significant differences among the hybrids in their per cent infected tillers and severity index where as, per cent smutted balls were found to be non-significant. Highest per cent smutted balls were observed in the hybrid Sahyadri (19.29) and lowest in H_y: 6444 (10.62). The least disease severity index and smutted balls per panicle was recorded in the cultivar H_y: 6444. The cultivars H_y: 6444 and Sahyadri were observed to be at par in the per cent of infected tillers (Fig 4.10).

Tab 4.4: Impact of false smut on hybrids in terms of per cent infected tillers, per cent smutted ball and disease severity index.

S. No.	Variety	Infected tillers (%)	Smutted balls (%)	Disease severity index
1.	Sahyadri	30.02	19.29	583.4
		(33.63)	(4.12)	
2.	KHR-2	53.57	14.37	802.61
		(47.23)	(3.71)	
3.	HY-6444	33.73	10.62	358.43
		(35.21)	(3.32)	
	CD (at 5%)	8.01	-	290.12

Note: Figures in parenthesis are transformed values

4.2 Conditions favouring the false smut

An attempt was made to know any relationship between the weather parameters prevailed (Tab 4.5) during the course of investigation (*Kharif*, 2003) and false smut incidence, severity in early, medium and late duration cultures. A comparative account is presented in the form of (Tab 4.6).

Table 4.5 : Weekly meteorological data during crop growth period (June 18 to November 11, 2003)

Week No.	Date		Temperature (°C)		Rainfall (mm)	Relative humidity (%)		Rainy days
			Maximum	Minimum		I	II	
25	June, 03	18-24	37.1	27.4	1.0	73	51	0
26		25-01	31.4	24.7	44.2	89	72	4
27	July, 03	02-08	30.3	24.9	45.4	92	68	4
28		09-15	31.6	25.0	46.1	92	74	5
29		16-22	31.7	24.9	20.8	92	73	2
30		23-29	30.1	24.2	256.4	92	80	5
31		30-05	29.7	24.6	72.2	93	80	5
32	Aug., 03	06-12	31.4	25.4	128.8	92	84	4
33		13-19	29.4	23.9	102.8	94	80	5
34		20-26	30.5	24.8	95.8	92	78	5
35		27-02	28.6	24.1	210.3	94	86	5
36	Sept., 03	03-09	27.3	23.8	61.1	93	86	4
37		10-16	28.6	24.0	27.2	93	81	2
38		17-23	31.1	24.2	72.4	94	79	3
39		24-30	31.2	24.0	70.5	92	72	4
40		01-07	31.1	22.8	20.2	92	67	2
41	Oct., 03	08-14	29.8	21.8	36.2	93	63	0
42		15-21	30.9	21.0	0.0	92	61	3
43		22-28	27.8	20.6	54.8	93	74	1
44		29-04	30.7	20.6	14.4	94	55	0
45	Nov., 03	05-11	30.4	15.8	0.0	92	38	0

In the early duration cultures, the incidence ranged from 6.59-56.84 per cent with per cent smutted balls ranging from 1.11-7.08. The disease index was recorded between 14.26 - 402.32.

In case of medium duration group, the incidence ranged between 10.5-36.08 per cent, per cent smutted balls between 1.3-6.29 and disease index with a range of 16.5-208.49.

The late duration varieties had incidence range in between 9.82-46.49 per cent, smutted balls per panicle per cent between 1.49-11.44 and disease index with a variation between 15.86-361.78.

The maximum and minimum temperature during the crop growth period ranged between 27.3-31.7^{o}C and 14.0-25.4^{o}C respectively. Relative humidity varied between 91-94 and minimum between 35-86 per cent. Number of rainy days were more in the meteorological weeks 28-36 and 38-41 as compared to the 44-46, which had not received any rainfall.

Early duration group flowered between 70-90 days (Tab 4.7). Medium and late durations between 85-105 and 105-120 days respectively. No particular trend in the distribution of the false smut incidence was observed in the early and medium duration groups. The present data (Tab 4.6) clearly indicates that false smut incidence and severity per panicle and disease index were more in the late duration in general with sixteen varieties showing high incidence, eight varieties with high per cent smutted balls and ten varieties with high disease index. This might be due to the inherent susceptibility of the

varieties. During all the duration varieties flowering, time rainfall was received and this might be one reason for disease incidence in all these duration groups.

Tab 4.7: Different duration varieties flowering period (range)

Duration	Date of sowing (weeks)	Date of transplanting (weeks)	Date of flowering (weeks)	Days of flowering
Early	25^{th} – 26^{th}	28^{th} – 30^{th}	34^{th} –37^{th}	70-90
Medium	27^{th} –28^{th}	31^{st} – 32^{nd}	36^{th} –39^{th}	85-105
Late	29^{th} –30^{th}	32^{nd} –34^{th}	38^{th} – 41^{st}	105-120
Hybrids	27^{th}-28^{th}	32^{nd}	37^{th} –38^{th}	105-110

4.3 Size of spore balls

The fifty spore balls measured using vernier calipers revealed their length and breadth. Length and breadth of the spore balls were found to be 0.69 cm and 0.49 cm respectively. The length of the balls observed ranged from 0.51 cm to 1.1 cm, where as the breadth was found to be in the range 0.31 cm to 0.71 cm.

4.4 Study of chlamydospores

The results of the various studies conducted *in-vitro* on chlamydospres of *Ustilaginoidea virens* are presented below.

4.4.1 Structure of chlamydospores.

Variations were recorded in the chlamydospores collected and studied from the different localities. Chlamydospores from the cultivar H_y: 6444, collected form the village Tendua, were spherical to elliptical and measured 4-6 x 3-5 μm where as chlamydospores from the varieties Aditya, Swarna and

HMT Sona (research farm) were hyaline, smooth and measured 3-8 x 3-5μm. Chlamydospores of the cultivar MTU-1010 (village Beerbara) revealed a spore size of 4-6 x 3-5 μm.

4.4.2 Characteristics and germinating ability of chlamydospores

Colour: The smut balls in the initial stage looks dark yellow in colour. With the ageing of the balls, they turn to dark green and further to dark black.

4.4.3 Effect of different pH concentrations on the chlamydospore germination.

Germination of the chlamydospores was influenced by the pH concentration (Tab 4.8). In general chlamydospore germination was favoured between the pH ranges 5.5 to 7.5. The chlamydospore germination was significantly high at 6.5 pH (82.52%) followed by 6.0 (72.41%). The least per cent germination was recorded at the acidic pH of 4.0 followed by 4.5. However, the alkaline range of 8.0 also did not favour the per cent germination of the chlamydospores. There was no significant difference in the per cent germination at these levels. This clearly reveals that pH has a major role in the germination of the chlamydospores. The acidic and basic ranges are found to adversely affect the germination per cent (Fig 4.11).

4.4.4 Effect of different glucose concentrations on the chlamydospore germination.

Chlamydospores were subjected to different glucose concentrations and observations were recorded for per cent germination to see any effect.

Significant germination was recorded at 0.1 per cent glucose concentration (71.7%). It was found that with an increase in the concentration of glucose, there was a steady decrease in the per cent germination (Tab 4.9). At concentrations, 0.1, 0.3, 0.5, 0.7, 0.9 and 1.1 per cent, the per cent spores germinated were 56.31, 43.53, 43.1, 34.19 and 25.36 respectively. Significant difference was observed even in 0.1 per cent and 0.3 per cent glucose concentrations where as the germination per cent at concentrations of 0.5 and 0.7 per cent were at par with each other. Significantly low per cent germination was observed at 0.9 and 1.1 per cent glucose concentrations (Fig 4.12).

Tab 4.9: Per cent germination of chlamydospores at different glucose concentrations

S. No.	Glucose concentration	Germination (%)
1	0.1	71.7 (58.08)
2	0.3	56.31 (48.71)
3	0.5	43.53 (41.01)
4	0.7	43.1 (41.01)
5	0.9	34.19 (35.45)
6	1.1	25.36 (29.83)
	CD (at 5%)	7.79

Note: Figures in parenthesis are transformed values

4.4.5 Effect of different temperatures on the chlamydospore germination

Influence of different temperatures on the germination of chlamydospores was studied (Tab 4.10). Temperature influenced the germination per cent of the chlamydospores. Maximum per cent germination

was recorded at 30°C (74.76) followed by 25°C (67.4). Least per cent germination of chlamydospores was observed at temperatures of 15°C and 40°C with 11.34 and 9.36 respectively (Fig 4.13).

Tab 4.10 : Per cent germination of chlamydospores at different temperatures

S. No.	Temperature (^{O}c)	Germination (%)
1	15	11.34 (18.90)
2	20	37.53 (37.60)
3	25	67.4 (55.37)
4	30	74.76 (61.96)
5	35	38.09 (30.02)
6	40	9.36 (17.36)
	CD (at 5%)	7.29

Note: Figures in parenthesis are transformed values

4.4.6 Effect of field water and nutrient solution on the chlamydospore germination

The germination per cent of chlamydospores in field water and standard nutrient solution was compared with each other (Tab 4.11). More per cent germination was recorded in field water (84.68) as compared to standard nutrient solution (68.29). They both differed significantly in the per cent germinations (Fig 4.14).

Tab 4.11: Per cent germination of chlamydospores in field water and nutrient solution

S. No.	Treatment	Germination (%)
1	Field water	84.68
		(68.27)
2	Nutrient solution	68.29
		(56.05)
	CD (at 5%)	6.08

Note: Figures in parenthesis are transformed values

4.5 Role of chlamydospores in infection

The chlamydospores were dusted, sprayed with fresh preparation made in sterilized field water and also germinated spore suspension was sprayed on the variety HMT Sona, grown on pots and maintained in the mist chamber. In none of the case, the disease symptoms of smut balls were observed. During the entire study, the plants were kept under congenial humid conditions in the mist chamber.

During the course of the studies this trial was repeated five times and during the entire course no symptoms developed. The control plants sprayed with water also did not show any smutted ball(s).

4.6 Seed health testing for false smut infection from seed lots

Seed health primarily emphasis on the presence or absence of disease causing organisms such as fungi, nematodes, bacteria etc and is very important to the crop production. In the present studies rice varieties *viz.*, Indira-9, Swarna, HMT Sona, MTU-1010, Mahamaya and Pusa Basmati-1 were tested for the per cent seed borne infection of *Ustilaginoidea virens*. Maximum per

cent infected seed (Tab 4.12) were observed in the seed lot of the cultivar (HMT Sona) 70.5. In other varieties infections of 57.75 per cent (MTU-1010), 51.50 per cent (Pusa Basmati-1), 36.75 per cent (Indira-9) and 33.0 per cent (Mahamaya) were found. However, severity of infected seed was found to be least in (Swarna) 31.0 per cent. In all the cases, the seed infection was restricted to the external seed borne nature only (Fig 4.15).

Tab 4.12: Per cent seed infection in different varieties

S. No.	Variety	Total seeds observed	Infected seeds	Per cent infection
1.	Indira-9	400	147	36.75
2.	Swarna	400	124	31.00
3.	HMT Sona	400	282	70.50
4.	MTU 1010	400	231	57.75
5.	Mahamaya	400	132	33.00
6.	Pusa Basmati-1	400	206	51.50

4.7 Yield loss assessment

Losses in grain yield due to false smut of rice caused by *Ustilaginoidea virens* were assessed on ten cultivars under high disease pressure in natural conditions.

Yield losses were calculated as per the method given by Singh and Dube (1978). Sahyadri recorded highest yield loss (15.51%) followed by MTU-1010 (15.35%), Pusa Basmati-1 (11.12%) and HMT Sona (10.68%) (Tab 4.13). The least per cent yield losses were recorded in Swarna (7.31), IR-64 (5.06), Aditya (4.86), Mahamaya (4.01), Rasi (3.93) and Kranti (3.17). The

present data clearly indicates that the parameters, incidence per cent and smutted balls per panicle are very important in determining the yield losses.

Sahyadri recorded high per cent of incidence (30.02) and per cent smutted balls per panicle (18.65). Therefore it also suffered highest per cent yield loss as compared to others (Fig 4.16).

CHAPTER-V

DISCUSSION

The results of the research programme entitled "Studies on false smut of rice in Chhattisgarh region" have been thoroughly discussed and corroborated in the light of research work done by various workers.

Rice has been documented as a source of food as far back as 2500 BC in history books. It has fed more people over a longer period of time than any other crop in the world and continues to do so. Half of the world's population is dependent on rice as a staple food. Hence it may be the most important plant on this earth as aptly projected (Shimamoto, 1995; Goff, 1999).

The false smut disease has been reported as a major concern to the farmers of important rice growing states of India including Andhra Pradesh, Assam, Jammu and Kashmir, Karnataka, Punjab, Kerala, Tamil Nadu, Uttar Pradesh and West Bengal. This disease is now known to occur in all rice growing tracts of India and reported to cause considerable losses in yield.

5.1 Per cent incidence, per cent grain infection and disease severity index in different duration cultivars and hybrids.

The data shows that the per cent infected tillers, smutted balls and severity index did not follow a particular trend. Among the different early cultivars studied, cultivar MTU-1010 showed the highest per cent of (56.84) infected tillers and hence high disease severity index (402.32) was also observed. The variety Rasi topped the list in the per cent smutted balls with

7.08. MTU-1010 showed 7.04 per cent smutted balls. In many cases it was found that with an increase in the per cent infected tillers, the per cent smut balls per panicle also increased and their coupled effect resulted in high disease severity index. Similar trends were not observed in all the varieties. Varieties like Abhaya showed high per cent of infected tillers (29.24), but showed relatively low per cent of smut balls per panicle (2.36) and hence low disease severity index (75.6) was observed. It is concluded from the findings that the cultivar MTU-1010 was highly susceptible for the false smut pathogen. Hence those varieties like MTU-1010, Patel Super, Rasi etc needs management of this disease, if grown by farmers. Cultivars such as IR-36, HKRH-1094 and ADTRH-16 etc which showed low disease severity can be recommended for false smut recurring tracts.

Findings, from the medium cultivar group showed significantly high incidence of false smut in the cultivar HMT Sona with infected tillers and smutted balls per cent of 36.08 and 6.29 respectively. Disease severity index was found to be 208.49. Similar trends were observed in Pusa Basmati-1 and Indira-9. Varieties Suldhan and Bamleshwari which showed very less disease severity indices of 19.31 and 16.50 respectively may well suit for endemic regions. Early duration varieties showed more severity index when compared to the medium varieties in the present studies.

In the late cultivar group, a total of sixteen varieties showed severe infection. Per cent infected tillers were found to be high among the cultivars like Jhilli, Rajibangla and Malagouri. Smutted balls per cent was recorded

maximum in the variety Parwa (11.44). Significantly high disease severity index were observed in the cultivars Parwa, Badshahbhog, Rajibangla, Jhilli, Pakshiraj, Dubraj and Bagmuchh. In the present studies, late varieties were found to be highly susceptible for the false smut disease than the early and medium cultivars.

A particular trend was not observed in the present studies in between early and medium duration varieties and incidence of false smut and per cent smutted balls per panicle. However, Rao (1964) reported that medium varieties were more prone to the false smut incidence and per cent smutted balls per panicle. In late duration group the disease severity index was very high in some cultivars because of high per cent incidence and smutted balls per panicle. The late duration cultivars were also reported to be more severely infected by false smut (Singh *et al*., 1987; Agarwal *et al*., 1990) corroborated with the present observation. During all the duration varietal flowering period, rainy days were recorded, which might be a reason for not pronounced differences in early and medium group as compared to late duration. Varietal character may also be one important reason for the differences in severity among the groups and also with in the group.

Hybrids also had high disease severity index as it was seen in late duration. In hybrids, highest disease severity index was recorded in KHR-2 (802.61), which also had the highest per cent infected tillers (53.57). Smutted balls per panicle were found to be high in Sahyadri (19.29%). Hy: 6444 had least smutted balls per panicle (10.62%). Xia (1989) and Mew and Misra

(1994) also reported that hybrids were more prone to false smut severity. Xia (1989) further identified that long duration flowering phase in hybrids favoured the severity.

5.2 Conditions favouring the false smut

The meteorological parameters were correlated with the infection and severity of false smut on the different duration cultivars. It was clearly observed that disease severity index was high with the late and hybrid cultivars as compared to early and medium duration cultivars. Hence it is inferred that some conditions including host plant resistance and duration of the cultivars might be responsible for the present effect.

Bhagat *et al*. (1991) and Yashoda *et al*. (2000) reported that weather parameters like low maximum temperature (<31°C), low rainfall, minimum temperature around 19°C and high relative humidity (> 90%) had significant effect on the false smut development. Correlation with the above findings, it was observed from the present studies that a maximum temperature of 27.3°C-31.7°C and minimum of 14.0 – 25.4°C and relative humidity of 91-94 per cent prevailed during the course of investigation. This might had more influence in disease development in late duration varieties. However, Agarwal *et al*. (1990) reported that drizzling weather conditions favours the disease incidence. In the present study the rainy days were recorded during all the duration flowering time. This might be one reason for disease incidence in all the duration varieties.

5.3.1 Size of spore balls.

Variation in size in general among the spore balls was observed in the present studies. The observation recorded on fifty spore balls clearly revealed that the length of spore balls ranged from 0.51 cm to 1.1 cm and breadth from 0.31 cm to 0.71 cm. Ou (1985) also reported spore balls reaching 1 cm or more in diameter agreeing with the present findings.

5.4 Study of chlamydospores

5.4.1 Structure of chlamydospores

Chlamydospores evaluated from the infected samples obtained from different localities showed variations in the spore sizes. This indicates that variability existed in the pathogen isolated from different localities. The chlamydospores obtained from the infected samples of the varieties Aditya, HMT Sona and Swarna revealed spore sizes of 3-8 x 3-5 μm, which were agreeing with the findings of Verma and Singh (1988). Hashioka (1971) observed spores with sizes of 4-6 x 3-5 μm from infected samples. In varieties Hy: 6444 and MTU-1010 the spore sizes were recorded of 4-6 x 3-5 μm. This agree with the above reports and also indicates variations in size of the spores of *Ustilaginoidea virens*.

5.4.2 Effect of different pH concentrations on the chlamydospore germination.

Solutions with pH concentrations of 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5 and 8.0 were used for studying the germinating ability of chlamydospores. The pH concentration of 6.5 was found to favour maximum germination (82.52%)

followed by pH of 6.0 (72.41%). Maximum inhibition of germination was found at pH of 4.0 where very less per cent of germination was recorded (10.66). Ou (1985) recorded more per cent germination of chlamydospores at pH of 6.02 - 6.72. The present finding corroborates with these reported results. Experimental results showed that with an increase in the acidity or alkalinity, the germination per cent of the chlamydospores reduced considerably confirming the reports of Tsai *et al*. (1996). They reported optimum of 5.0 to 8.0 pH as congenial for the germination and growth of chlamydospores.

5.4.3 Effect of different glucose concentrations on the chlamydospore germination

Among the different glucose concentration tested (0.1%, 0.3%, 0.5%, 0.7%, 0.9% and 1.1%) highest germination was observed at the concentration of 0.1 per cent (71.7%). There was a steady decrease in the per cent germination of chlamydospores, with increase in the concentration of the carbon source. Concentrations of 0.5 and 0.7 per cent showed almost similar germination per cent of 43.53 and 43.1 respectively. The present studies revealed that carbon sources have got good influence on the germination per cent of chlamydospores. Similar findings were also reported by Sharma and Dave (1992).

5.4.4 Effect of different temperatures on the chlamydospore germination

Significantly high germination of the chlamydospores were observed at the temperatures of 30°C (74.76%) and 25°C (67.4%). Germination of chlamydospores was recorded at all the different temperature levels studied but

with varying per cent. Least per cent germination was found at 40°C (9.36). Similar observations were recorded by Wang *et al.* (1997). They reported the favourable temperature for the germination of chlamydospores to be in the range of 25-30°C. Studies revealed that with an increase or decrease in the temperature from the ambient of 30°C, there was a steady decrease in the germinating ability of the chlamydospores.

5.4.5 Effect of field water and nutrient solution on the chlamydospores germination

Chlamydospores germinated more in field water (84.08%) as compared to nutrient solution (68.29%). Significantly high per cent germination was observed in field water than that of nutrient solution. (Fig 4.14) depicts the difference in germination observed at both the treatments. These observations need further studies as how the field water influenced more germination.

5.5 Role of chlamydospores in infection

The chlamydospores were dusted, sprayed with fresh preparation made in sterilized field water and also germinated spore suspension was sprayed on the variety HMT Sona at flowering stage under controlled conditions, failed to incite the infection of the false smut pathogen and symptoms. The plants treated did not show any alteration in their physiology also as in the case with the incidence of disease. Kulkarni and Moniz (1975) successfully inoculated rice plants by applying chlamydospore suspension to the ovaries. Chhottaray (1991) reported that the spraying of chlamydospore suspension at flowering period produced maximum infection. However, in the present studies the mist

chamber results contradicted with the observations recorded during field studies. No authentic inoculation method is also reported and adopted for the evaluation of the cultivars for resistance to false smut in the coordinated research programmes of the country. Therefore the artificial inoculation for false smut disease needs further efforts.

5.6 Seed health testing for false smut infection from seed lots.

Seed from six popular varieties Indira-9, Swarna, Mahamaya, Pusa Basmati-1, MTU –1010 and HMT Sona were evaluated for the per cent infection of false smut in seed lots. The spores of *Ustilaginoidea virens* were detected from the seed washings in all the six varieties tested. However, their per cent infection in the varieties varied. HMT Sona showed maximum per cent of infected seed (70.5) followed by MTU-1010 (57.75), Pusa Basmati-1 (51.50), Indira-9 (36.75) and Mahamaya (33.0) whereas the least number of infected seed were found in the variety Swarna (31.0%). Duhan and Jakhar (2000) also reported 0.05-0.5 per cent incidence of false smut in the rice seed samples tested in seed washing method. It is concluded from the present studies that the seed from the cultivars HMT Sona, MTU-1010 etc should be seed treated before sowing in order to avoid the primary inoculum.

5.7 Yield loss assessment

In the present investigation, attempts were made to assess the yield loss caused by false smut disease in ten promising rice cultivars under heavy disease pressure. Maximum loss in yield was reported from the hybrid cultivar Sahyadri (15.51%). The data also showed that maximum per cent of yield loss

was observed in those cultivars where disease severity index was more accompanied by a reduction in grain weight too. The total loss in yield caused by false smut accounted due to infected tillers, smutted grains per panicle and due to decrease in the grain weight of the infected panicles. The present findings were corroborating with the reports of Ikegami (1955) who also concluded that grain weight of infected panicle decreased due to increase in the number of spore balls per panicle. Severe losses in yield were also reported by Singh and Dube (1978) and Ansari *et al*. (1988) agreeing with the present findings.

CHAPTER-VI

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

The present investigation entitled “Studies on false smut of rice in Chhattisgarh region” was carried out in the Department of Plant Pathology, I.G.K.V., Raipur. The investigation mainly consisted of six parts *i.e.,* i. The host pathogen interaction and reaction of promising rice cultivars belonging to the early, medium, late durations and hybrids in terms of per cent incidence, per cent grain infection and disease severity index. ii. Conditions favouring the false smut development iii. *In-vitro* studies on the characteristics and germinating ability of the chlamydospores of the pathogen. iv. Artificial inoculations with chlamydospores for disease initiation v. Seed health testing for false smut infection from seed lots and vi. Yield loss assessments.

Summary and Conclusions

Rice is an agronomically and nutritionally, one of the world’s most important staple food crop, as approximately half of the world population is dependent on it for a significant proportion of their calorie intake. Many biotic and abiotic stresses causing severe reduction in the yield from year to year are reported on this crop. False smut disease has attained the constraint status offlate looking to its constant recurrence and severity in most parts of rice

growing ecosystems. Because it has a direct impact on the panicle spikelets, the yield losses are also attaining prominence.

Twenty-five early, medium, late duration cultivars and three hybrids were evaluated during the course of investigation. It was observed that in the early cultivars, MTU –1010 showed highest per cent of infected tillers and the highest severity index, followed by Patel Super. Highest per cent smutted balls were observed in the cultivar Rasi, followed by MTU-1010. However, the least per cent infected tillers were observed in Parbhani Culture. Least per cent of smutted balls and severity index was recorded in ADTRH-16. The varieties Poornima, Parbhani Culture, IR-36, HKRH-1094 and ADTRH-16 showed very low disease severity index in the present studies.

In the medium duration cultivars, HMT Sona showed maximum per cent of infected tillers, smutted balls per panicle and also disease severity index whereas the least was observed in the cultivar Bamleshwari.

Cultivar Jhilli showed the maximum per cent incidence and the cultivar Parwa recorded the highest per cent of smutted balls and disease severity index in the late duration cultivars. Least disease severity index and smutted balls were observed in Duokang-1 where as MTU-1001 showed the least per cent infected tillers. Late varieties suffered with more per cent smutted balls per panicle and severity index as compared to the early and medium cultivars. This might be due to the low maximum temperatures and favourable relative humidity prevailed during the study period.

In hybrids, all the three showed relatively high per cent infected tillers, smutted balls and disease severity index. The cultivar KHR-2 recorded maximum severity index as compared to the early, medium and late duration varieties. Sahyadri recorded the highest per cent of smutted balls where as KHR-2 showed the maximum per cent incidence. Out of all the hybrids tested, protracted length of flowering period may be the reason for more infection as concluded by others also (Xia, 1989).

Weather conditions were reported to play an important role in the false smut incidence. In the present investigations, rainy days were almost experienced at the time of flowering in all the duration varieties. Therefore, this might have equally contributed to disease incidence in all the durations. However, the maximum temperature ranged between 27.3^{o}C-31.7^{o}C with high relative humidity (91-94%) and good amount of precipitation (1174.7mm) which might have further contributed for the more disease incidence in late duration group. Such findings were also earlier reported by Yashoda *et al.* (2000).

The chlamydospores obtained from infected samples on different varieties and different localities showed variability among them. Chlamydospores from the cultivars Aditya, HMT Sona and Swarna from the research farm measured 3-8 x 3-5µm where as spores from variety Hy: 6444 and MTU-1010 measured 4-6 x 3-5µm. The spore balls measured also showed variable length in the range of 0.51cm-1.1cm and breadth of 0.31-0.71cm.

In-vitro studies were conducted for assessing the germinating ability of the chlamydospores of the pathogen. The chlamydospores were shown to germinate more at the pH of 6.5 followed by 6.0. Extremely acidic and basic conditions were found to inhibit the spore germination. It clearly shows that a pH which is nearly neutral incites good germination of chlamydospores.

Among the different glucose concentrations tested, higher germination was obtained at 0.1 per cent followed by 0.3 per cent. With a steady increase in the concentration of the carbon source, germination per cent of the chlamydospores decreased steadily.

Temperatures also influenced the germination of chlamydospores. At 30^{o}C and 25^{o}C maximum per cent germination was recorded. At extreme low (15^{o}C) and extremely high (40^{o}C) very less germination of the spores were observed. Practically less or no germination occurred at higher temperatures. Maximum temperature in the range of 25^{o}C–35^{o}C prevails during the *Kharif* season which might be favouring high germination of chlamydospores and there by more infection. Field water was shown to incite the best germination in chlamydospores when compared to germination at standard nutrient solution.

Dusting of the chlamydospores, spraying of fresh spore preparation in sterilized field water and germinated spore suspension of the chlamydospores at the flowering stage on the potted rice plants resulted in no infection. It is inferred from this experiment that no infection in these trials conducted and

repeated five times might be due to some other reason, which needs further investigation.

All the six varieties seed showed infection of *Ustilaginoidea virens* though the per cent infected seed varied from variety to variety. Maximum infected seed were observed in the variety HMT Sona followed by MTU-1010, Pusa Basmati-1, Indira-9, Mahamaya and the least per cent in the variety Swarna. The per cent infection traced out in these varieties is reasonably good to pose a threat in the disease spread contributing to the primary inoculum.

Yield loss assessments were done on ten popular rice cultivars *viz.*, Sahyadri, Swarna, HMT Sona, IR 64, Aditya, Kranti, MTU-1010, Pusa Basmati-1, Mahamaya and Rasi. The cultivar Sahyadri recorded the highest loss in yield among all the varieties followed by MTU-1010, Pusa Basmati-1 and HMT Sona. The varieties Swarna, IR-64, Aditya , Mahamaya and Rasi suffered less loss in yield. Lowest per cent loss in yield was observed in the cultivar Kranti. This might be due to the low disease severity. In addition to the per cent incidence, smutted balls per cent per panicle, the chaffy grains and 1000-grain weight in healthy and infected panicles studied clearly indicated that due to infection, the latter two parameters were also effected considerably. This might be the reason for more per cent yield loss in varieties like Sahyadri, MTU-1010, Pusa Basmati-1 etc.

SUGGESTIONS FOR FUTURE WORK:

With the increasing importance of false smut disease, intensive efforts and investigations need to be further carried out to understand the factors

contributing the perpetuation of the pathogen, infection and spread. The targeted studies will definitely help in devising appropriate management practices. Therefore, in short the following suggestions were made:

1. How the pathogen perpetuates and the conditions favouring the perpetuation.
2. Time of infection, mode of infection and spread of the pathogen needs detailed study.
3. Interaction of the environmental conditions needs to be worked in detail, so that the forewarning systems can be developed.
4. The role of seed infection and its contribution as primary inoculum need to be worked more precisely, so that the further quick spread of the disease to the new geographical regions can be averted. This also helps in reducing the inoculum in already reported areas.

"STUDIES ON FALSE SMUT OF RICE IN CHHATTISGARH REGION"

by

Anish Muraleedharan

ABSTRACT

The present investigation entitled "Studies on false smut of rice in Chhattisgarh region" was conducted in the Department of Plant Pathology, Saveer mist chamber and at the research farm, I.G.K.V., Raipur (C.G.).

Twenty-five each early, medium, late duration cultivars and three hybrids were evaluated for their per cent incidence, per cent grain infection per panicle and disease severity index. All the duration group varieties showed susceptibility to false smut, though with varying levels. The effect of false smut disease was pronounced more in the late duration cultures and hybrids as compared to early and medium durations. No particular trend was observed in the disease development within the cultures of different durations groups. Varietal character might have also played an important role for the differences in false smut severities among the cultivars.

The weather conditions prevailed also influenced the false smut incidence and severity index. Rainy days were almost experienced during all the durations varietal flowering period, which might have also influenced the false smut incidence in all the duration cultivars. Low maximum temperature for a protracted period and high relative humidity (>90%) during the crop growth period along with good amount of precipitation might have played an important role in all the duration cultivars and especially in late duration group.

Spore balls and chlamydospores of the pathogen studied under *in-vitro* conditions showed variability. Per cent germination of the chlamydospores was found to be influenced by the pH, glucose concentrations and different temperatures. The near neutral pH (6.5), glucose concentration of 0.1 per cent and temperatures around 30°C enhanced the germination per cent. In field

water, per cent chlamydospores germinated were more as compared to standard nutrient solution.

The plants inoculated with spore dusting, spore suspension and germinated spore suspension sprayed on the susceptible variety did not initiate the infection and symptoms. Therefore, the artificial inoculation methods need further investigation and detailed study.

None of the six varieties studied for per cent seed infection of false smut were free from the pathogen. Maximum per cent infected seed were observed in the varieties HMT Sona, MTU-1010 and Pusa Basmati-1. The seed borne infection may also contribute for the primary inoculum and spread of the pathogen from one geographic to other regions.

All the ten promising rice cultivars evaluated for the losses in yield showed considerable losses but with varying levels. Maximum loss in yield was observed in the cultivars Sahyadri, followed by MTU-1010, Pusa Basmati-1 and HMT Sona. In addition to the direct losses due to smutted balls, indirect losses due to increase in chaffy grains and decrease in the 1000-grain weight of infected panicles also might have contributed to the yield loss. It may be inferred that under congenial weather conditions the false smut disease incidence can cause considerable losses in yield.

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Tab 4.1: Impact of false smut on the early cultivar group in terms of per cent infected tillers, per cent smutted balls and disease severity index.

S. No.	Variety	Infected tillers (%)	Smutted ball (%)	Disease severity index
1	NDR-359	14.96 (22.19)	1.74 (1.46)	24.58
2	Tulsi	20.97 (26.66)	2.27 (1.55)	54.77
3	Vandana	15.29 (25.54)	2.34 (1.63)	33.18
4	MTU-1010	56.84 (49.25)	7.04 (2.62)	402.32
5	IR-64	14.62 (22.05)	1.48 (1.38)	22.03
6	IR-42342	18.66 (24.70)	2.25 (1.61)	49.91
7	R-548-89-6	14.92 (21.84)	1.44 (1.37)	23.88
8	Parbhani culture	6.59 (14.54)	3.07 (1.77)	20.79
9	Nidhi	16.49 (22.11)	1.91 (1.47)	29.88
10	Patel super	35.36 (35.93)	4.36 (2.06)	166.51
11	Aditya	17.45 (24.31)	3.78 (2.00)	65.79
12	Danteshwari	21.74 (27.47)	3.73 (1.97)	78.03
13	PAC 80035	32.34 (33.61)	4.74 (2.21)	126.21
14	IR-36	15.74 (22.30)	1.46 (1.32)	16.69
15	Annada	13.32 (20.66)	2.89 (1.69)	42.42
16	ADTRH-16	12.14 (20.02)	1.11 (1.25)	14.26
17	Poornima	12.59 (19.82)	2.01 (1.46)	21.35
18	Abhaya	29.24 (31.81)	2.36 (1.63)	75.6
19	HKRH-1094	13.83 (21.08)	1.46 (1.36)	16.09
20	NDR-97	19.86 (25.84)	2.35 (1.58)	39.9
21	UDHR 2019	27.47 (30.92)	2.9 (1.75)	69.84
22	Rasi	19.43 (24.78)	7.08 (2.46)	141.38
23	Kasturi	18.87 (24.88)	5.25 (2.22)	101.82
24	PR 102	17.07 (23.44)	4.62 (2.09)	85.43
25	R-371-1	18.16 (24.43)	1.92 (1.52)	38.13
	CD (at 5%)	7.21	0.54	77.57

Note : Figures in parenthesis are transformed values

Tab 4.2: Impact of false smut on the medium cultivar group in terms of per cent infected tillers, per cent smutted balls and disease severity index.

S. No.	Variety	Infected tillers (%)	Smutted ball (%)	Disease severity index
1	Mahamaya	18.54 (24.80)	4.36 (2.17)	61.97
2	R-1142-604-1-1	12.48 (20.19)	1.66 (1.45)	20.65
3	Triguna	17.04 (23.02)	2.39 (1.62)	44.53
4	Shyamala	13.56 (21.35)	1.72 (1.46)	22.83
5	Suraksha	22.42 (27.53)	1.63 (1.42)	37.98
6	R-1097-44-3-1	15.47 (22.58)	4.03 (2.02)	72.37
7	R-1072-360-1-1	13.29 (20.78)	3.12 (1.83)	42.63
8	R-650-1817	14.59 (22.28)	2.04 (1.51)	26.11
9	HMT Sona	36.08 (35.88)	6.29 (2.47)	208.49
10	BG-380-2	15.88 (23.18)	3.83 (1.97)	69.77
11	Bamleshwari	10.54 (18.41)	1.88 (1.50)	16.5
12	Kranti	11.82 (19.54)	3.72 (1.84)	22.34
13	Pusa Basmati-1	35.74 (35.75)	5.72 (2.33)	191.98
14	Jaya	27.15 (30.04)	4.57 (2.14)	143.78
15	R-1055-1629-4-1	10.5 (18.44)	2.69 (1.71)	29.97
16	Madhuri	10.56 (18.50)	2.48 (1.59)	28.05
17	R-979-1528-1	22.34 (26.95)	1.58 (1.40)	48.89
18	Sasyasree	23.89 (28.22)	2.9 (1.75)	62.71
19	Dodana	24.51 (26.21)	2.09 (1.56)	60.29
20	BPT-5204	23.49 (28.28)	2.67 (1.64)	69.48
21	Suldhan	15.43 (22.92)	1.3 (1.32)	19.31
22	RAU-3037	25.45 (29.19)	3.15 (1.82)	58.29
23	Jalpan	23.64 (27.83)	5.38 (2.33)	154.26
24	Indira-9	25.89 (29.73)	5.79 (2.31)	101.13
25	R-6335	30.76 (32.50)	2.62 (1.73)	89.36
	CD (at 5%)	7.96	0.55	79.01

Note: Figures in parenthesis are transformed values

Tab 4.3: Impact of false smut on the late cultivar group in terms of per cent infected tillers, per cent smutted balls and disease severity index .

S. No.	Variety	Infected tillers (%)	Smutted ball (%)	Disease severity index
1	Swarna	21.15 (26.07)	1.85 (1.51)	39.68
2	Duokang-1	11.4 (19.05)	1.49 (1.36)	15.86
3	MTU 1001	9.82 (17.84)	2.83 (1.72)	26.68
4	R-304-34	12.72 (19.58)	1.62 (1.43)	19.45
5	Phalguna	11.54 (19.26)	5.41 (2.29)	67.43
6	R-1075-34-1	20.97 (25.92)	2.74 (1.63)	43.8
7	Karnal Local B	20.79 (25.80)	5.31 (2.36)	109.36
8	DRRH-25	29.18 (31.52)	3.72 (1.97)	108.84
9	Pakshiraj	30 (29.73)	8.88 (3.01)	263.52
10	Parwa	32.98 (34.22)	11.44 (3.36)	361.78
11	Malagouri	36.72 (36.81)	3.66 (1.96)	130.86
12	Raji Bangla	37.47 (36.89)	7.86 (2.78)	285.62
13	Gangabarud	27.88 (30.52)	4.98 (2.24)	87.28
14	Jhilli	46.49 (42.91)	5.81 (2.43)	278.1
15	Vasumati	30.25 (33.12)	6.57 (2.61)	201.42
16	NSNI-27	18.04 (24.06)	5.23 (2.18)	105.8
17	Bagmuchh	36.18 (34.43)	7.06 (2.63)	235.01
18	Gahuwan	30.04 (32.17)	4.42 (2.14)	122.18
19	Ambe Mohar 157	27.47 (30.31)	3.24 (1.86)	111.52
20	Dokramechha	31.59 (33.60)	6.22 (2.68)	195.02
21	Badshahbhog	31.91 (33.50)	9.74 (3.14)	321.52
22	Chinnor	31.67 (33.82)	5.49 (2.32)	158.14
23	Dubraj	28.46 (31.51)	8.58 (2.84)	252.1
24	Gopal Bhog	17.72 (24.57)	2.74 (1.70)	52.84
25	Tulsi Amrit	16.9 (23.58)	1.96 (1.48)	34.34
	CD (at 5%)	8.85	0.56	115.06

Note: Figures in parenthesis are transformed values

Tab 4. 8 : Per cent germination of chlamydospores at different pH concentrations

S. No.	pH concentration	Germination (%)
1	4.0	10.66
		(17.33)
2	4.5	19.52
		(25.94)
3	5.0	28.79
		(31.88)
4	5.5	47.6
		(43.61)
5	6.0	72.41
		(60.65)
6	6.5	82.52
		(66.60)
7	7.0	44.34
		(41.78)
8	7.5	40.45
		(39.26)
9	8.0	20.845
		(26.55)
	CD (at 5%)	9.56

Note: Figures in parenthesis are transformed values

Tab 4.13: Effect of false smut on the yield of different varieties

S. No.	Variety	Infected tillers (%)	Smutted balls (%)	Disease severity	Grain weight from 50 panicles		Difference in weight	Yield loss (%)
					Unsmutted	Smutted		
1	Swarna	27.65	1.94	53.64	95.20	70.02	25.18	7.31
2	Sahyadri	30.02	18.65	559.87	210.95	101.96	108.99	15.51
3	HMT Sona	36.08	6.14	221.53	89.80	63.22	26.58	10.68
4	IR-64	18.14	3.22	58.41	168.73	121.67	47.06	5.06
5	Aditya	17.45	3.83	66.83	166.46	120.07	46.39	4.86
6	Kranti	11.82	2.45	28.96	212.78	155.68	57.10	3.17
7	MTU-1010	56.84	6.78	385.38	160.14	116.88	43.26	15.35
8	Pusa Basmati-1	35.74	5.64	201.57	122.86	84.64	38.22	11.12
9	Mahamaya	15.43	1.30	20.66	223.07	165.13	57.94	4.01
10	Rasi	14.96	1.69	25.28	142.90	105.36	37.54	3.93

Tab 4.6: Distribution of false smut disease in different duration cultivars

Duration	Per cent incidence						Per cent smutted balls				Disease severity index						
	1-5	6-10	11-15	16-20	21 & above	Total	1-3	3-6	7 & above	Total	1-25	26-50	51-75	76-100	101-150	150 & above	Total
Early	-	1	9	9	6	25	16	7	2	25	8	6	4	2	3	2	25
Medium	-	3	8	2	12	25	14	11	-	25	5	7	7	1	2	3	25
Late	-	1	3	5	16	25	7	10	8	25	2	4	2	1	6	10	25
Hybrids	-	-	-	-	3	3	-	-	3	3	-	-	-	-	-	3	3

Appendix

Anova 1 : Per cent infected tillers in early duration cultivars

Source of variation	d.f	M.S.	F ratio	CD (5%)	SEm±
Replication	9	157.60	2.35	7.21	2.59
Treatment	24	464.14	6.93		
Error	216	66.98			
Total	27027				
G. Mean	24.43				

Anova 2 : Per cent infected tillers in medium duration cultivars

Source of variation	d.f	M.S.	F ratio	CD (5%)	SEm±
Replication	9	220.42	2.7	7.96	2.86
Treatment	24	262.79	3.22		
Error	216	81.63			
Total	25923				
G. Mean	25.36				

Anova 3 : Per cent infected tillers in late duration cultivars

Source of variation	d.f	M.S.	F ratio	CD (5%)	SEm±
Replication	9	145.78	1.45	8.85	2.18
Treatment	24	422.73	4.19		
Error	216	100.84			
Total	33239				
G. Mean	29.31				

Anova 4 : Per cent infected tillers in hybrids

Source of variation	d.f	M.S.	F ratio	CD (5%)	SEm±
Replication	9	53.04	0.73	8.006	2.69
Treatment	2	552.97	7.61		
Error	18	72.62			
Total	2890.6				
G. Mean	38.69				

Anova 5 : Per cent smutted balls in early duration cultivars

Source of variation	d.f	M.S.	F ratio	CD (5%)	SEm±
Replication	9	0.11	0.29	0.54	0.195
Treatment	24	1.38	3.61		
Error	216	0.381			
Total	116.54				
G. Mean	1.74				

Anova 6 : Per cent smutted balls in medium duration cultivars

Source of variation	d.f	M.S.	F ratio	CD (5%)	SEm±
Replication	9	0.71	1.79	0.55	0.197
Treatment	24	1.13	2.88		
Error	216	0.39			

Total	118.78
G. Mean	1.79

Anova 7 : Per cent smutted balls in late duration cultivars

Source of variation	d.f	M.S.	F ratio	CD (5%)	SEm±
Replication	9	0.77	1.89	0.56	0.2
Treatment	24	3.18	7.85		
Error	216	0.405			
Total	170.88				
G. Mean	2.23				

Anova 8 : Per cent smutted balls in hybrids

Source of variation	d.f	M.S.	F ratio	CD (5%)	SEm±
Replication	9	0.49	0.64	-	0.28
Treatment	2	1.62	2.09		
Error	18	0.77			
Total	21.65				
G. Mean	3.74				

Anova 9 : Disease severity index in early duration cultivars

Source of variation	d.f	M.S.	F ratio	CD (5%)	SEm±
Replication	9	8452.61	1.09	77.57	27.82
Treatment	24	57477.1	7.42		
Error	216	7744.86			
Total	1E+07				
G. Mean	70.43				

Anova 10 : Disease severity index in medium duration cultivars

Source of variation	d.f	M.S.	F ratio	CD (5%)	SEm±
Replication	9	14597.1	1.82	79.01	28.34
Treatment	24	28639.9	3.56		
Error	216	8034.77			
Total	3E+06				
G. Mean	68.15				

Anova 11 : Disease severity index in late duration cultivars

Source of variation	d.f	M.S.	F ratio	CD (5%)	SEm±
Replication	9	47254.3	2.77	115.06	41.28
Treatment	24	107927	6.33		
Error	216	17038.4			
Total	7E+06				
G. Mean	145.11				

Anova 11 : Disease severity index in hybrids

Source of variation	d.f	M.S.	F ratio	CD (5%)	SEm±
Replication	9	103585	1.09	290.12	97.64
Treatment	2	493267	5.17		
Error	18	95345.2			

Total	4E+06
G. Mean	581.48

Anova 12 : Effect of different pH concentrations on the chlamydospore germination

Source of variation	d.f	M.S.	F ratio	CD (5%)	SEm±
Treatment	8	2105.8	23	9.56	3.38
Error	63	91.56			
Total	22614				
G. Mean	39.29				

Anova 13 : Effect of different glucose concentrations on the chlamydospore germination

Source of variation	d.f	M.S.	F ratio	CD (5%)	SEm±
Treatment	5	793.04	13.31	7.79	2.73
Error	42	59.58			
Total	6467.5				
G. Mean	42.36				

Anova 14 : Effect of different temperatures on the chlamydospore germination

Source of variation	d.f	M.S.	F ratio	CD (5%)	SEm±
Treatment	5	3333.09	50.35	7.29	2.87
Error	54	66.198			
Total	20240				
G. Mean	38.2				

Anova 15 : Effect of field water and nutrient solution on the chlamydospore germination

Source of variation	d.f	M.S.	F ratio	CD (5%)	SEm±
Treatment	1	1046.61	17.04	6.08	2.09
Error	26	61.425			
Total	2643.7				
G. Mean	62.16				

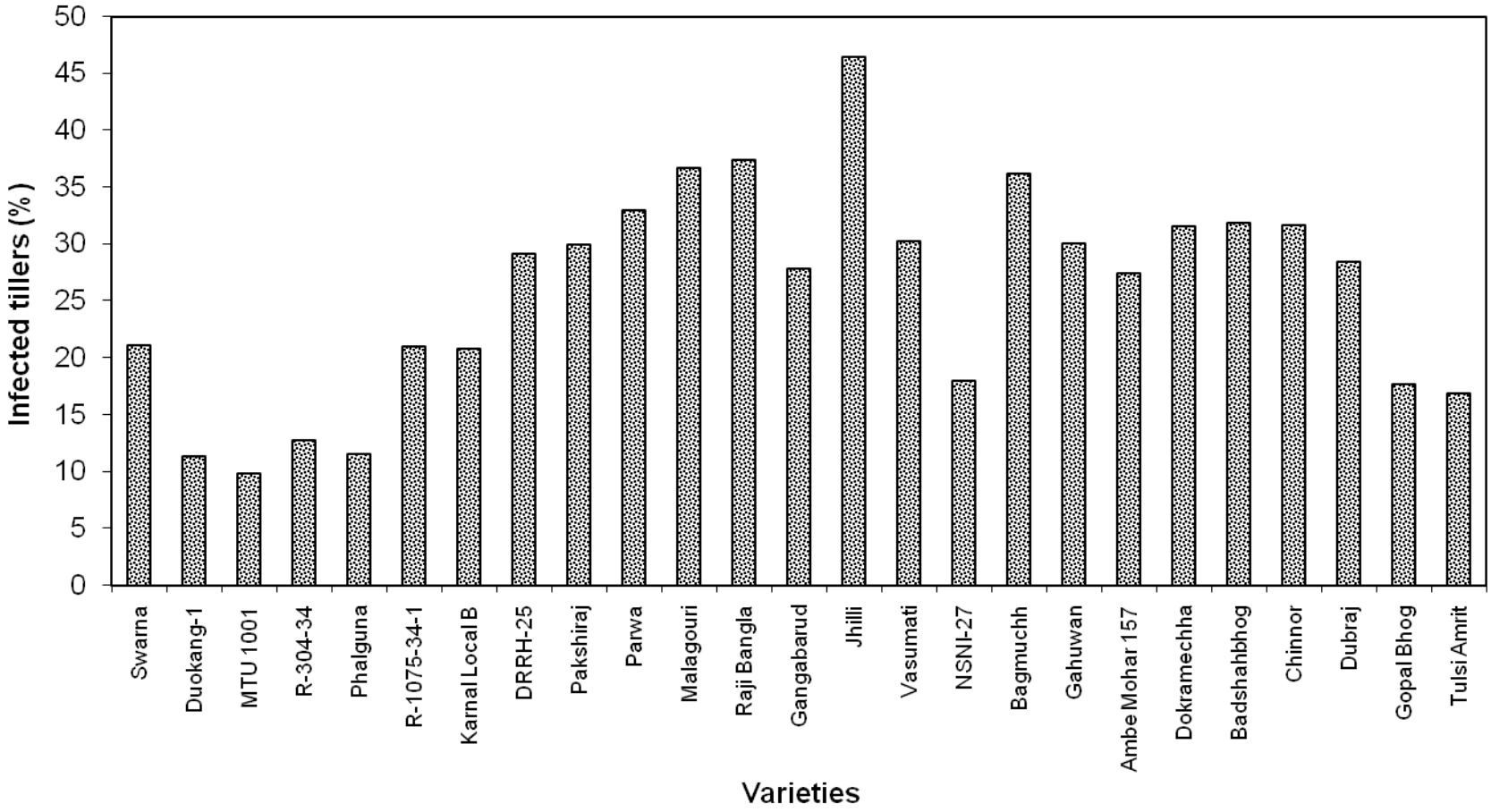


Fig. 4.7 : Infected tillers per cent in late duration varieties

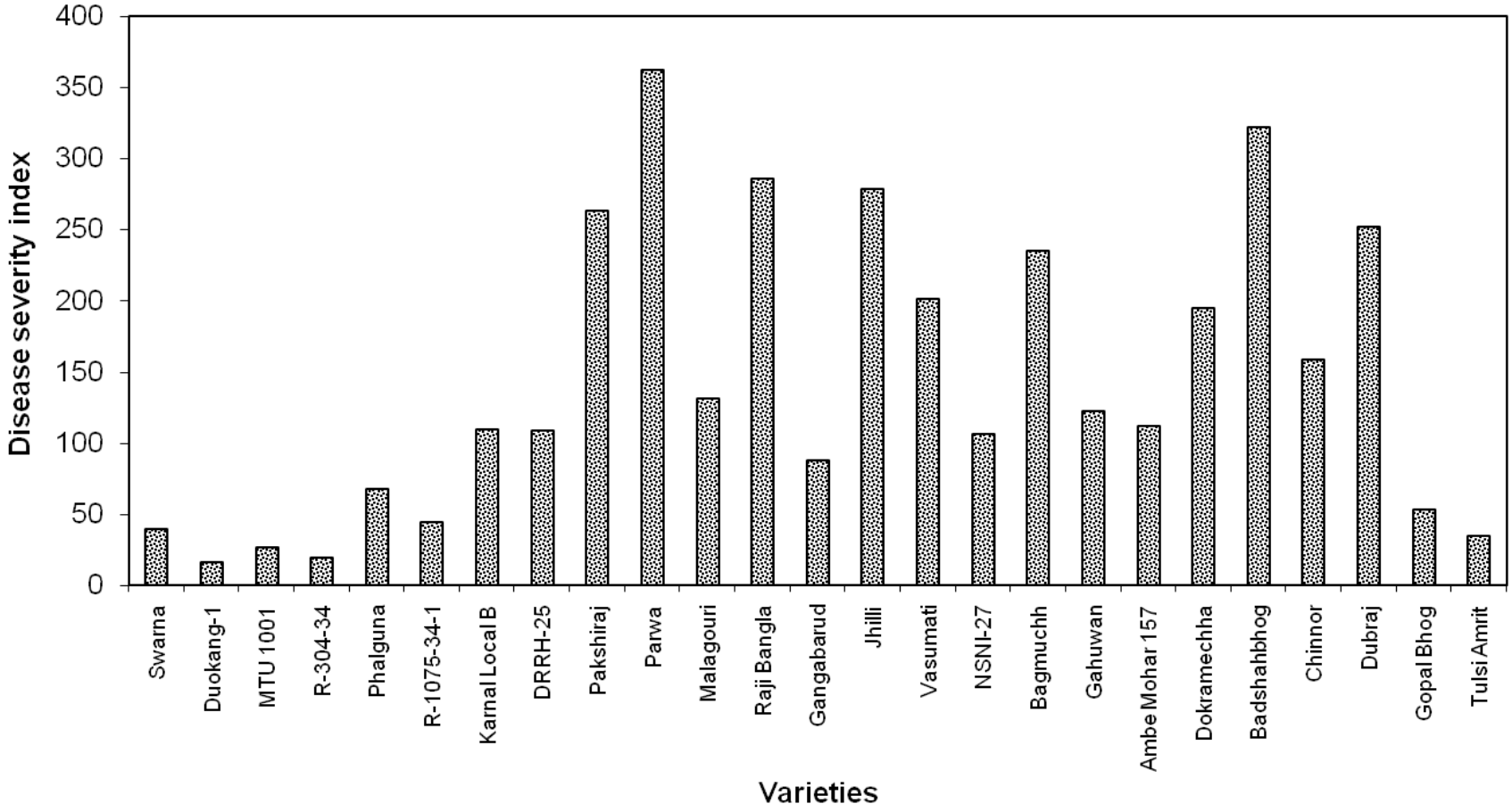


Fig. 4.9 : Disease severity index of false smut in late duration varieties

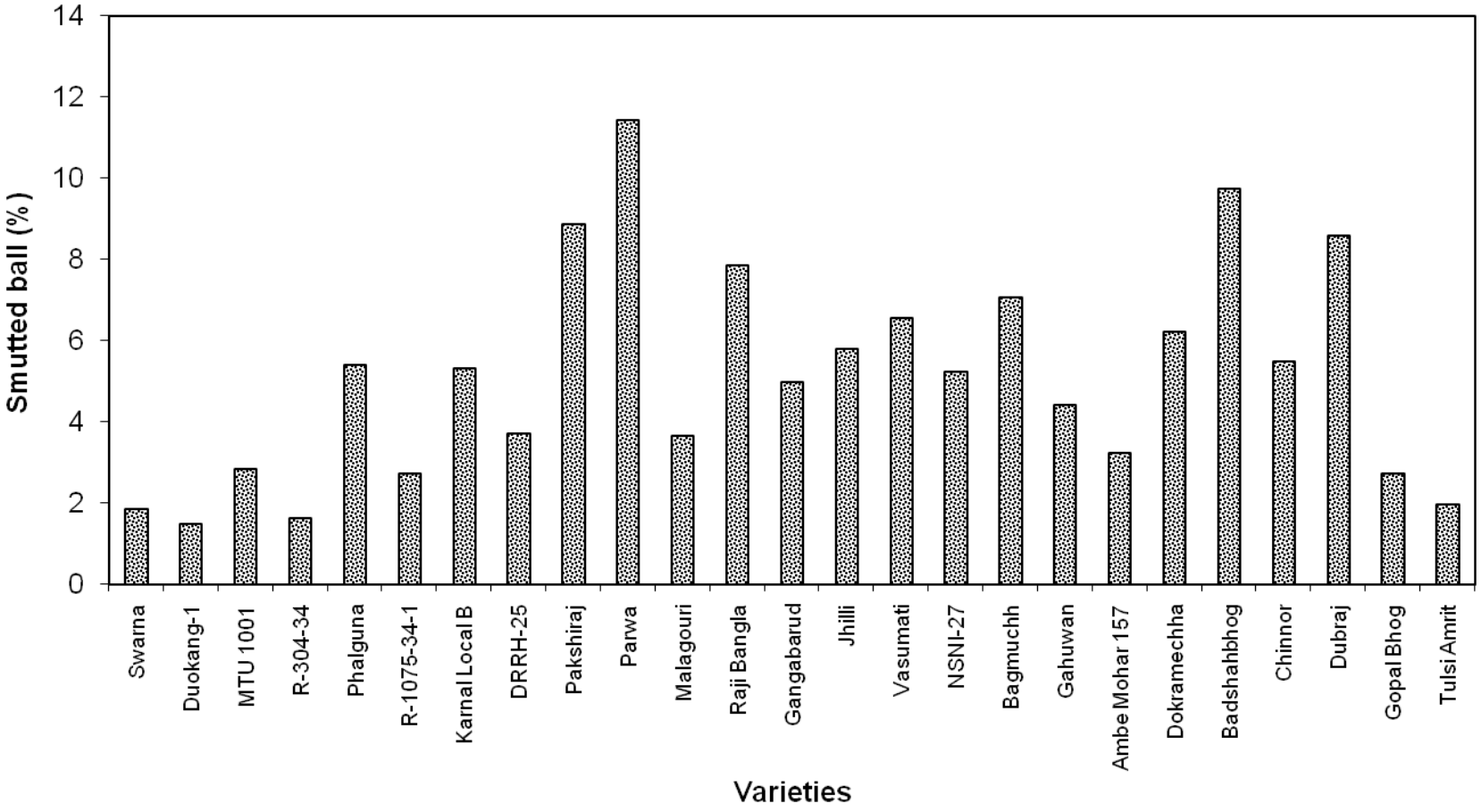


Fig. 4.8 : Smutted balls per cent in late duration varieties

Variety	Smutted ball (%)	Variety	Infected tillers (%)	Variety	Disease severity
Swarna	1.85	Swarna	21.15	Swarna	39.68
Duokang-1	1.49	Duokang-1	11.4	Duokang-1	15.86
MTU 1001	2.83	MTU 1001	9.82	MTU 1001	26.68
R-304-34	1.62	R-304-34	12.72	R-304-34	19.45
Phalguna	5.41	Phalguna	11.54	Phalguna	67.43
R-1075-34-1	2.74	R-1075-34-1	20.97	R-1075-34-1	43.8
Karnal Local B	5.31	Karnal Local B	20.79	Karnal Local B	109.36
DRRH-25	3.72	DRRH-25	29.18	DRRH-25	108.84
Pakshiraj	8.88	Pakshiraj	30	Pakshiraj	263.52
Parwa	11.44	Parwa	32.98	Parwa	361.78
Malagouri	3.66	Malagouri	36.72	Malagouri	130.86
Raji Bangla	7.86	Raji Bangla	37.47	Raji Bangla	285.62
Gangabarud	4.98	Gangabarud	27.88	Gangabarud	87.28
Jhilli	5.81	Jhilli	46.49	Jhilli	278.1
Vasumati	6.57	Vasumati	30.25	Vasumati	201.42
NSNI-27	5.23	NSNI-27	18.04	NSNI-27	105.8
Bagmuchh	7.06	Bagmuchh	36.18	Bagmuchh	235.01
Gahuwan	4.42	Gahuwan	30.04	Gahuwan	122.18
Ambe Mohar 157	3.24	Ambe Mohar 157	27.47	Ambe Mohar 157	111.52
Dokramechha	6.22	Dokramechha	31.59	Dokramechha	195.02
Badshahbhog	9.74	Badshahbhog	31.91	Badshahbhog	321.52
Chinnor	5.49	Chinnor	31.67	Chinnor	158.14
Dubraj	8.58	Dubraj	28.46	Dubraj	252.1
Gopal Bhog	2.74	Gopal Bhog	17.72	Gopal Bhog	52.84
Tulsi Amrit	1.96	Tulsi Amrit	16.9	Tulsi Amrit	34.34

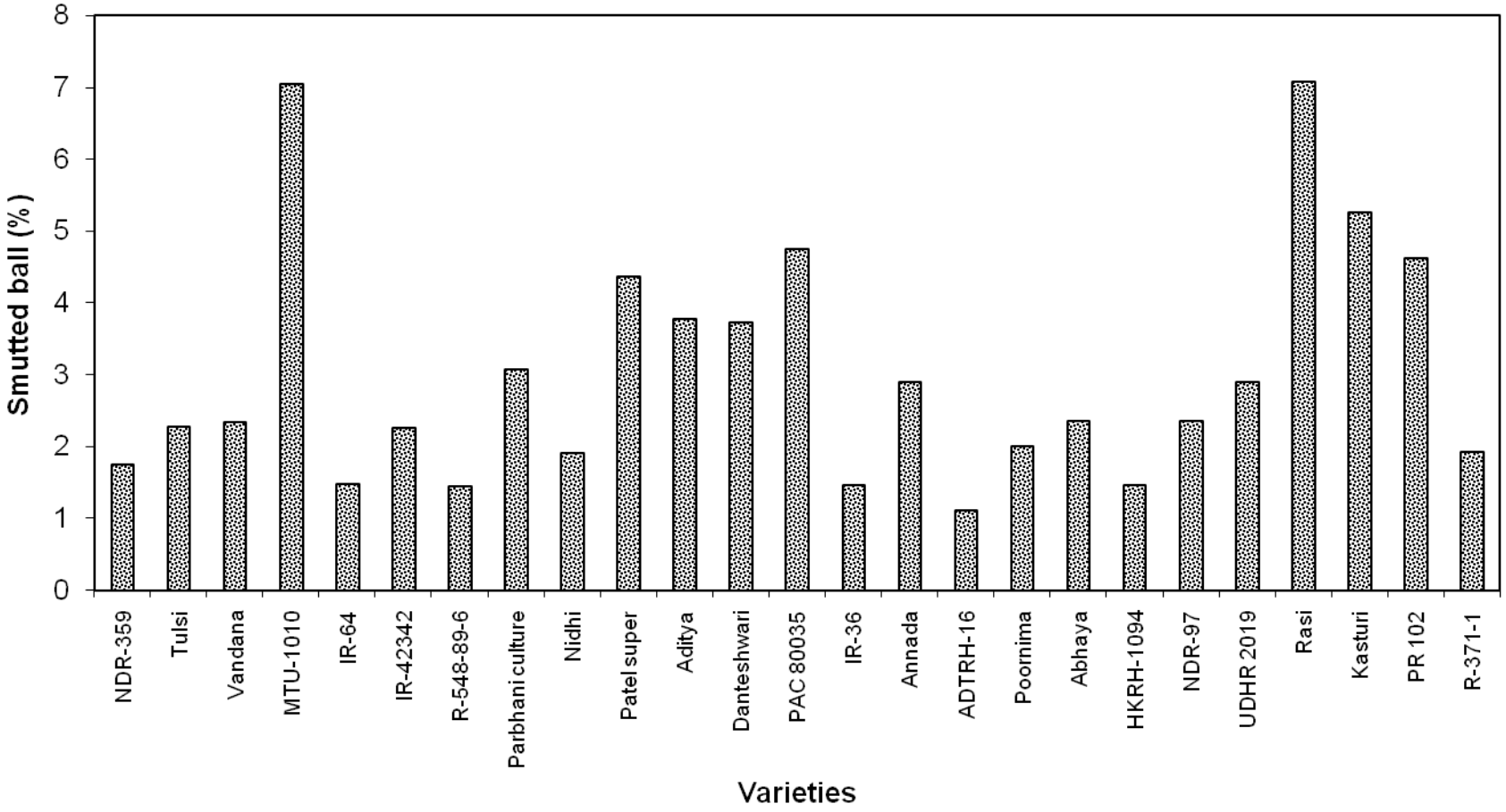
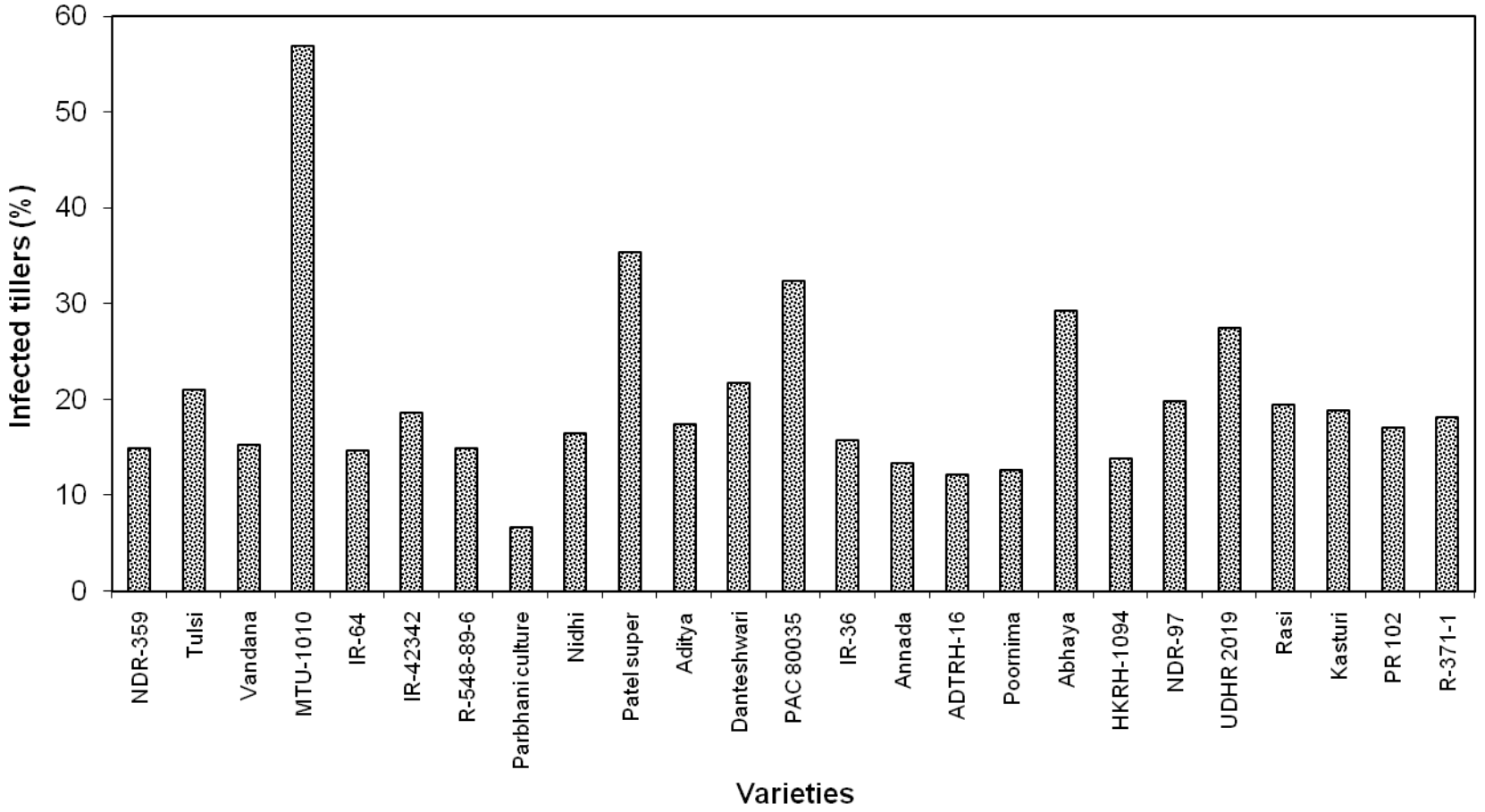


Fig. 4.2 : Smutted balls per cent in early duration varieties


Infected tillers (%)
60
50
40
30
20
10
0
NDR-359
Tulsi
Vandana
MTU-1010
IR-64
IR-42342
R-548-89-6
Parbhani culture
Nidhi
Patel super
Aditya
Danteshwari
PAC 80035
IR-36
Annada
ADTRH-16
Poornima
Abhaya
HKRH-1094
NDR-97
UDHR 2019
Rasi
Kasturi
PR 102
R-371-1
Varieties

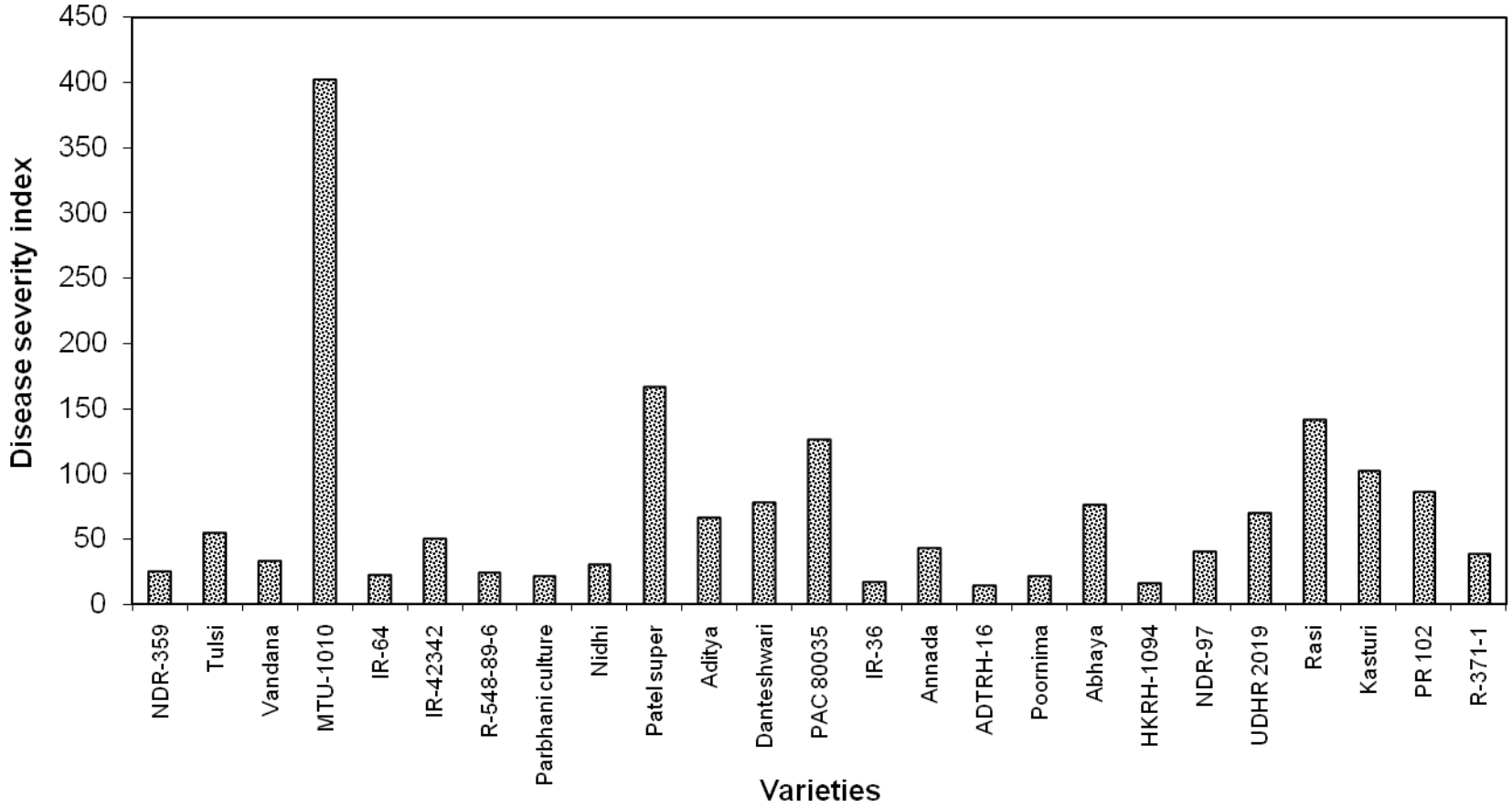
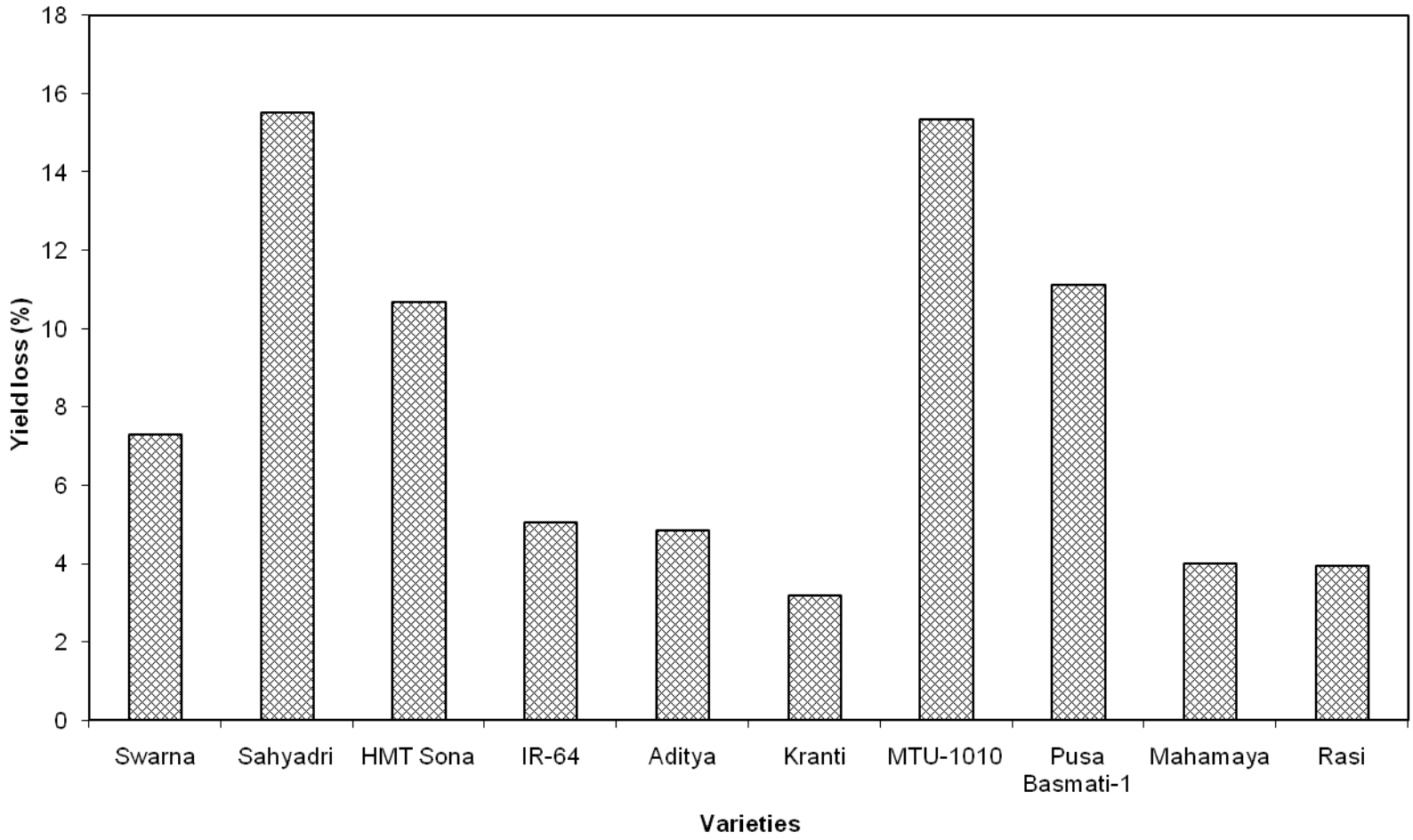


Fig. 4.3 : Disease severity index of false smut in early duration varieties


18
16
14
12
10
8
6
4
2
0
Yield loss (%)
Swarna
Sahyadri
HMT Sona
IR-64
Aditya
Kranti
MTU-1010
Pusa Basmati-1
Mahamaya
Rasi
Varieties

Variety	Smutted ball (%)	Variety	Infected tillers (%)	Variety	Disease severity
NDR-359	1.74	NDR-359	14.96	NDR-359	24.58
Tulsi	2.27	Tulsi	20.97	Tulsi	54.77
Vandana	2.34	Vandana	15.29	Vandana	33.18
MTU-1010	7.04	MTU-1010	56.84	MTU-1010	402.32
IR-64	1.48	IR-64	14.62	IR-64	22.03
IR-42342	2.25	IR-42342	18.66	IR-42342	49.91
R-548-89-6	1.44	R-548-89-6	14.92	R-548-89-6	23.88
Parbhani culture	3.07	Parbhani culture	6.59	Parbhani culture	20.79
Nidhi	1.91	Nidhi	16.49	Nidhi	29.88
Patel super	4.36	Patel super	35.36	Patel super	166.51
Aditya	3.78	Aditya	17.45	Aditya	65.79
Danteshwari	3.73	Danteshwari	21.74	Danteshwari	78.03
PAC 80035	4.74	PAC 80035	32.34	PAC 80035	126.21
IR-36	1.46	IR-36	15.74	IR-36	16.69
Annada	2.89	Annada	13.32	Annada	42.42
ADTRH-16	1.11	ADTRH-16	12.14	ADTRH-16	14.26
Poornima	2.01	Poornima	12.59	Poornima	21.35
Abhaya	2.36	Abhaya	29.24	Abhaya	75.6
HKRH-1094	1.46	HKRH-1094	13.83	HKRH-1094	16.09
NDR-97	2.35	NDR-97	19.86	NDR-97	39.9
UDHR 2019	2.9	UDHR 2019	27.47	UDHR 2019	69.84
Rasi	7.08	Rasi	19.43	Rasi	141.38
Kasturi	5.25	Kasturi	18.87	Kasturi	101.82
PR 102	4.62	PR 102	17.07	PR 102	85.43
R-371-1	1.92	R-371-1	18.16	R-371-1	38.13

Variety	Smutted ball (%)	Variety	Infecte (%)
Mahamaya	4.36	Mahamaya	
R-1142-604-1-1	1.66	R-1142-604-1-1	
Triguna	2.39	Triguna	
Shyamala	1.72	Shyamala	
Sursha	1.63	Sursha	
R-1097-44-3-1	4.03	R-1097-44-3-1	
R-1072-360-1-1	3.12	R-1072-360-1-1	
R-650-1817	2.04	R-650-1817	
HMT Sona	6.29	HMT Sona	
BG-380-2	3.83	BG-380-2	
Bamleshwari	1.88	Bamleshwari	
Kranti	3.72	Kranti	
Pusa Basmati-1	5.72	Pusa Basmati-1	
Jaya	4.57	Jaya	
R-1055-1629-4-1	2.69	R-1055-1629-4-1	
Madhuri	2.48	Madhuri	
R-979-1528-1	1.58	R-979-1528-1	
Sasyasree	2.9	Sasyasree	
Dodana	2.09	Dodana	
BPT-5204	2.67	BPT-5204	
Suldhan	1.3	Suldhan	
RAU-3037	3.15	RAU-3037	
Jalpan	5.38	Jalpan	
Indira-9	5.79	Indira-9	
R-6335	2.62	R-6335	