INTRODUCTION

India is the second largest producer as well as consumer of rice in the world. In India total area under cultivated of rice is 43.86 million with production 112.91 million tones and with productivity is about 3.62 tonnes per hectare during 2017-18 (Anonymous 2019a). In Punjab it is the most widely grown Kharif crop and occupied 3.06 million hectares with a production of 19.9 million tonnes and its average yield was 6.52 tonnes per hectare during 2017-18 (Anonymous 2019b). False smut or Green Smut or Pseudo smut of rice caused by the fungal pathogen, Ustilaginoideaviresens s(Cooke)Takahashi, was first reported from Tirunelveli in Tamil Nadu (Cooke 1878) and Kernel smut of rice is also known as grain smut (Biswas 2001), is caused by the pathogen Tillettibarclayana, was recorded first time in Egypt in 1999 (Ismail 2003). The typical symptoms of false smut appear at the maturity stage and in kernel smut symptom appear at grain formation stage of rice crop.In case of false smut individual grain is transformed into smutted balls which changed from orange to yellowish green at the maturity (Kumar2012)but in kernel smut individual grain in the panicle transformed into black powder spores (Singh 1998).

In false smut the Chlamydosporoes shape varied from elliptical, globose to irregularly round with prominent spines on the outer surface, initially in white colony that changed to yellow and finally became green with thick and double layer wall on media (Pillaet al., 2017) and played an important role in the secondary infection of the host (Zhou et al., 2008).In kernel smut the spores are globose or elliptical, light to dark brown in young stage then transformed into black color at maturity (Pandey2015).On the germination the teliospores give rise to promycelium bearing the primary sporidia which are long, cylindrical to produce secondary sporodia (Allantoid and Filliform) are responsible for floral infection under favourable conditions (Chahal 2001; Elshafey 2013). The growth characteristics on media of T. barclayana found white cottony colour and powdery, the colony was convex, deeply imbedded and incorporated within media. Yield loss from the Ustilaginoideaviresens and Tillettibarclayana was from 5 to 85% (Ladhalakshmiet al., 2012) and 5 to 15% (Priyaet al., 2018) respectively in different regions of India on different varieties(CGKB 2014; Sharma et al., 1993).False smut and kernel smut causes quantitative and qualitative losses at 25 to 30°C temperature (Salam et al., 2016).Relative humidity 70-80% and not much rainfallfavoured the false smut but high relative humidity (RH > 85%) and rain showers at the time of ear emergence highly favour the kernel smut disease (RKMP 2011). The major incidence of rice false smut disease can be avoided by planting rice varieties in such a way that the crops do not flower during mid-October to mid-November (Nessa 2017). By manipulating the time is easy way to controlling the incidence of false smut (Ahonsi and Adeoti 2003; Brooks et al., 2011). The incidence of kernel smut of rice is more in the early maturing varieties than medium and latematuring variety (Singh and Pavgi 1970; Singh 1975).

The present study to examine the effect of sowing time and weather parameters on incidence and severity of false smut and kernel smut and attempt has been made to...
Parameters on false smut and kernel smut of rice

**MATERIAL AND METHODS**

**Collection of diseased samples**

The field experiments were conducted at Research Farms of Guru Kashi University, Department of Plant Pathology, Talwandi Sabo, Bathinda, Punjab, during Kharif season 2018-19. The selected varieties *i.e.* PR111, PR122, PR114, PR127 and Pusa44 were sown at different sowing date at fortnight interval i.e. 10th May, 25th May and 10th June 2018. Split plot design was used and plot size was maintained 3x2.5m² and 15x20cm plant spacing was maintained. All cultural practices followed according to the package practices of PAU. Observations were recorded at the harvesting time as the number of panicle affected in the selected plants and number of florets affected per panicle among randomly selected plants. The disease severity and disease incidence was calculated as (Singh and Dube 1978).

\[
\text{Disease incidence (\%) = } \frac{\text{Number of diseased panicle}}{\text{Total number of inspected panicle}} \times 100
\]

\[
\text{Disease Severity (\%) = Percent infected tillers} \times \text{Percent smutted balls}
\]

\[
\text{Percent smutted balls} = \frac{\text{Number of smutted balls/panicle}}{\text{Total number of grains/panicle}} \times 100
\]

The data recorded in all the experiments was statistically analyzed using EDA statistical programme, at Central Computer Laboratory, Guru Kashi University, Talwandi Sabo and the differences among means were tested by using Least Significant Difference (LSD) values at 5% level of probability.

**Isolation of culture**

The sterilized samples of false smutted balls washed with 1% sodium hypochlorite solution for 1 min followed by 50% ethanol, were dried by keeping them between filter paper and put the cut pieces of diseased samples on the YPDA media. The samples were incubated in the BOD at 27 ± 2°C for about two weeks to get the pure culture of fungus. Similarly, the sterilized teliospores of black smut transferred onto a 2% water agar. The plates were incubated at 25 ± 2°C for 15 days in the BOD for germination of teliospores.

**Purification and maintenance of both cultures:**

**Hyphal tip method** (Aboul-Nasr et al., 2014) used for purification of both cultures (False smut and black smut) under laminar flow conditions and inoculated petriplates incubated at the desired temperature in the BOD (Biological Oxygen Demand). As the fungus grow in the center the advancing edge of the mycelium having hyphal tips well separated from each other. These hyphal tips transferred individually to separate agar slants in the test tubes using red hot inoculation needle. These hyphal tips in the tubes developed into pure colony.

**Identification and characterization of Pathogens:**

**False smut (Ustilaginoideavirens)**

The characteristics of the fungal colony on media and the details of their morphology were recorded and culture was identified by using the slides and observes it under the microscope at 40 X.

**Black smut (Tilletiabarcleyana)**

Identification of *T.barclayana* isolates was carried out according to the morphological, microscopic characteristics and type of teliosporegermination in Plant Pathology Laboratory using the key given by Fischer and Holton (1957).

**Weather Parameter data**

The weather data collected from RRS (Bathinda) from August to November 2018, to know the effect of different sowing date of rice on incidence of false smut and kernel smut of rice.

**RESULTS AND DISCUSSION**

**Effect of different sowing date on incidence and severity of Diseases**

During Kharif, 2018-19, the results (Table 1 and Graph 1.2) revealed that the disease incidence and severity percentage of both collected false smut (Figure 1) and kernel smut (Figure 2) in all three sowing dates varied with different varieties.

**False smut**

False smut disease incidence and severity (Table 1) increased steadily with delay in sowing. The late sowing of rice was recorded highest incidence 4.54, 9.63, 15.2, 6.60, 27.4 and severity 1.38, 4.60, 11.3, 5.85, 12.0 percentage at flowering stage during October to November as compare to early sowing with minimum disease incidence 0.99, 0.52, 1.12, 0.92, 5.49 and severity 0.13, 0.03, 0.20, 0.18, 1.25 percentage amongst three sowing dates. Nessa(2017) also conclude major incidence of rice false smut disease can be avoided by planting rice varieties in such a way that the crops do not flower during mid-October to mid-November. Narinder and Singh (1989) also observed that therice plants transplanted early, found less incidence i.e. 47% and 48.2% when transplanted on 5 and 25 July, respectively.

**Kernel smut**

Kernel smut disease incidence and severity (Table 1) decreased steadily with delay in sowing. The early sowing of rice was recorded maximum disease incidence 7.46, 13.7, 26.9, 7.68, 17.9 and severity 12.1, 6.60, 47.2, 12.7, and 20.4 percentage at flowering stage during August to September as compare to late sowing with minimum disease incidence 3.62, 2.99, 8.72, 4.64, 3.83 and severity 0.21, 0.07, 0.64, 0.18, 0.25 percentage were recorded amongst three sowing dates. The pervious study showed that the short duration varieties and early sowing varieties suffer more than late maturing varieties (RKMP 2011; Anonymous 2016).
TABLE: 1 Disease Incidence (DI %) and disease severity (DS %) of false smut at Kernel smut at different sowing date

<table>
<thead>
<tr>
<th>Varieties</th>
<th>False smut</th>
<th>Kernel smut</th>
<th>False smut</th>
<th>Kernel smut</th>
<th>False smut</th>
<th>Kernel smut</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DI(%)</td>
<td>DS(%)</td>
<td>DI(%)</td>
<td>DS(%)</td>
<td>DI(%)</td>
<td>DS(%)</td>
</tr>
<tr>
<td>PR111</td>
<td>0.99</td>
<td>0.13</td>
<td>7.46</td>
<td>12.1</td>
<td>4.37</td>
<td>0.60</td>
</tr>
<tr>
<td>PR122</td>
<td>0.52</td>
<td>0.03</td>
<td>13.7</td>
<td>6.60</td>
<td>7.25</td>
<td>0.47</td>
</tr>
<tr>
<td>PR127</td>
<td>1.12</td>
<td>0.20</td>
<td>26.9</td>
<td>47.2</td>
<td>11.5</td>
<td>2.33</td>
</tr>
<tr>
<td>PR114</td>
<td>0.92</td>
<td>0.18</td>
<td>7.68</td>
<td>12.7</td>
<td>5.46</td>
<td>2.60</td>
</tr>
<tr>
<td>PUSA44</td>
<td>5.49</td>
<td>1.25</td>
<td>17.9</td>
<td>20.4</td>
<td>8.26</td>
<td>9.11</td>
</tr>
<tr>
<td>Mean</td>
<td>1.80</td>
<td>0.36</td>
<td>14.7</td>
<td>19.8</td>
<td>7.69</td>
<td>3.03</td>
</tr>
</tbody>
</table>

**FIGURE 1:** Development stages of false smut in the field

**GRAPH 1:** Disease Incidence of False and Kernel smut of rice at different sowing date

**GRAPH 2:** Disease Severity of False and Kernel smut of rice at different sowing date
Identification and characterization of Pathogens:

**False smut**

After 7-14 days of incubation the chlamydospores of *Ustilaginoideavirescens* germinate to produced milky white colony with fluffy mycelium with flat or slightly convex surface, compact and leathery mycelium (Plate-FS1) which appeared orange or yellowish (Plate-FS2) and the mycelium show continued its growth on the PDYA slant (Plate-FS3). Sharma and Joshi 1975; Baitet et al., 2014 studied the growth and sporulation of *Ustilaginoideavirescens*. It produce creamy white colony with fluffy, compact and leathery mycelium, almost round, later on they became orange yellow and finally olive green and powdery.

**Kernel smut**

In the *Tilletiabarclayana* the teliospores germinated into restricted colonies after cultured on the water agar (Plate-KS1). These were then be cultured directly on solid media (PDYA) (Plate-KS2). After 14 days of incubation at 19 °C with a 12 h light cycle typically produce white- smooth leathery surface and raised colony deeply imbedded on PDYA slant (Plate-KS3). Similar observation of culture colonies of *Tilletiabarclayana* recorded in pervious study by Chahalet al., 2001 and Elshafey 2013.

Microscopic study of spores and mycelium:

**False smut**

The chlamydospores (from the outer region of the smut ball) were round to elliptical, thick and double walled. They appear yellow color in center and their thick wall appears black. (Slide-F1) and there germination was observed under compound microscope at 10X (Slide-F2) after inoculation on PDYA, mycelium was slender, branched, septate hyphae bear conidia (Slide-F3). Similar microscopic study recorded in pervious study (Ladhalakshmi et al., 2012 and Rani 2014).

**Kernel smut**

The spore (teliospore/ Teleutospore) of *Tilletiabarclayana* appear light brown and while few were brown to black in color and round in shape (slide F3) under compound microscope. Similarly Singh (1998) observe the teleutospores are pulverulent, light brown to black, globose or sub-globeu measuring 15-32 in diameter or 22.5-28.7 in size with or without an appendage/apiculus. On germination, it was observed teleutospores give rise to promycelium (Slide K2), bear cluster of primary sporidia which germinate to secondary sporidia called Filiform (Slide K3) and Allantoid. (Slide K4). Chahalet al.,(2001) observed germination of matureteliospores and found that the primary sporidia give rise to filliform and allantoidsporidia.

Effect of weather conditions on incidence of false smut and kernel smut of rice

Weather data (Table 2) revealed that there is significant relationship of the five most growing varieties (PR111, PR122, PR127, PR114 and Pusa44) in Punjab related to false smut incidence with

1) **False smut**

Weather data (Graph 3) revealed that there is significant relationship of the five most growing varieties (PR111, PR122, PR127, PR114 and Pusa44) in Punjab related to false smut incidence with low temperature, low relative humidity and low or no rainfall. The weather conditions with Max and Min temperature (29.7 and 14.3°C), Max and Min RH (79.8 and 39.6%) and no Rainfall for these five varieties favour the higher incidence 4.54, 9.63, 15.2, 6.60, 27.4% respectively of false smut in the late sowing
when the crop flowered on October to November observed as compared to early sowing when the crop got flowered during last week of August to mid-September with Max and Min temperature (34.1 and 24.8°C), Max and Min RH (82.6 and 58.6%), Rainfall (94mm) and number of rainfall days (6) with less incidence 0.99, 0.52, 1.12, 0.92, 5.49% respectively. The previous study showed that the incidence of false smut is favored by high relative humidity 70-80%, warm weather temperature between 25 and 30°C and not much affected by rainfall, late sowing (Salam et al., 2016).

2) Kernel smut
Weather data (Graph 4) revealed that there is significant relationship of the five most growing varieties (PR111, PR122, PR127, PR114 and Pusa44) in Punjab related to Kernel smut incidence with high temperature (Max. and Min.), High relative humidity (Max. and Min.), High rainfall and number of rainfall days (6) with less incidence 0.99, 0.52, 1.12, 0.92, 5.49% respectively. The pervious study showed that the incidence of false smut is favored by high relative humidity 70-80%, warm weather temperature between 25 and 30°C and not much affected by rainfall, late sowing (Salam et al., 2016).

<table>
<thead>
<tr>
<th>Sowing time</th>
<th>Flowering time</th>
<th>No. of Rainy Days</th>
<th>Total Rainfall (mm)</th>
<th>Temperature (°C)</th>
<th>Relative Humidity (%)</th>
<th>Percent disease incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>10th May</td>
<td>Aug. to Sep.</td>
<td>6</td>
<td>94</td>
<td>34.1</td>
<td>24.8</td>
<td>False Smut: PR111 0.99, PR122 0.52, PR127 1.12, PR114 0.92, Pusa44 5.49</td>
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<tr>
<td>25th May</td>
<td>Sep. to Oct.</td>
<td>2</td>
<td>43</td>
<td>32.9</td>
<td>20.3</td>
<td>False Smut: PR111 4.37, PR122 7.25, PR127 11.5, PR114 5.46, Pusa44 8.26</td>
</tr>
<tr>
<td>10th June</td>
<td>Oct. to Nov.</td>
<td>0</td>
<td>0</td>
<td>29.7</td>
<td>14.3</td>
<td>False Smut: PR111 9.63, PR122 27.5, PR127 6.60, PR114 2.99, Pusa44 3.62</td>
</tr>
</tbody>
</table>

TABLE: 2 Effect of weather conditions on *U. virens* and *T. barclayana*

<table>
<thead>
<tr>
<th>Rainfall (mm) + Temp(°C) + RH(%)</th>
<th>0</th>
<th>0.5</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
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<tr>
<td>PDI (False Smut)</td>
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<td>Total no. of rainy days</td>
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<td>Total rainfall (mm)</td>
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<td>Max. temp(°C)</td>
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<tr>
<td>Min. temp(°C)</td>
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<td>Max. RH(%)</td>
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<td>Min. RH(%)</td>
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GRAPH: 3 Weather Effect on Incidence of false smut at different flowering period
CONCLUSION
The result revealed that during Kharif season (2018) the maximum incidence (4.54, 9.63, 15.2, 6.60, 27.4%) and severity (1.38, 4.60, 11.3, 0, 12.0%) of false smut recorded on third sowing (10 June) while maximum incidence (26.9, 17.9, 13.7, 7.68, 7.46%) and severity (47.2, 20.4, 12.7, 12.12, 6.60%) of kernel smut recorded on first sowing (10 May). There was significant relationship recorded between the disease incidence, relative humidity and temperature.

The result also revealed that there is no significant influence of rainfall on false smut disease, but with high rainfall, temperature and relative humidity the incidence and severity of kernel smut is maximum with variety PR127. Hence maximum incidence of false smut was found when flowering stage of crop during October to November whereas kernel smut incidence was more in August to September during the flowering stage of crop. Therefore present studies will helpful for use of proper control measure and appropriate time to decrease to yield loss.

REFERENCES


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Rice Knowledge Management Portal (2011). http://digitalknowledgecentre.in