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Yield loss assessment in rice (*Oryza sativa*) due to false smut infection

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ABSTRACT

Rice false smut caused by *Ustilaginoidea virens* is a destructive inflorescence disease threatening rice production worldwide. The disease is emerging in many rice growing countries including India. Estimation of yield loss helps to understand the importance of the disease and hence appropriate measures for its management may be devised. Therefore, an investigation was conducted in farmers' field of Odisha during *kharif* 2017. The disease incidence, chaffiness and yield loss for 20 rice genotypes were assessed following a standard method. Disease severity was calculated based on the number of smut ball in an infected panicle. False smut incidence varied from 6–33% while the disease severity ranged from 0.33–17.25% in different genotypes. The highest disease incidence was observed in Pooja (33.33%) followed by Varsha Dhan (16.67%) and Sarala (13.89%). The highest disease severity was observed in Pooja (17.25%) followed by Utkal Prava (10.46%) and Moti (8.89%). The healthy panicles have relatively higher weight and number of grain than the smut panicles. The smut panicle contained more number of chaffy grains than the healthy panicle. The yield loss of rice due to false smut infection varied between 0.10–5.14% in different genotypes. Maximum yield loss occurred in Moti (5.14%) followed by Gayatri (4.60%). The finding is significant as it indicates the emergence of false smut as a threat to rice production.

Key words: False smut, Rice, Yield loss

Rice (*Oryza sativa* L.) is the most important cereal crop in Asia. In India, the production and productivity of rice is 112.90 million tonnes and 2585 kg/hectare respectively, cultivated in an area of 42.94 million ha. In Odisha, the production and productivity of rice is 6.52 million tonnes and 2009 kg/ha respectively (2017–18), cultivated in an area of 3.79 million ha (India Agristat 2018). Among the diseases affecting rice production, false smut is an important and emerging disease worldwide. The disease is caused by *Ustilaginoidea virens* (Cooke) Takahashi, which is a flower infecting fungus. The favourable factors for disease outbreak include high humidity and temperature between 25 and 30°C (Yashoda *et al*. 2000), late sowing and high soil fertility (Ahonsi *et al*. 2000) as well as using high amount of nitrogen. The major symptom of false smut is the appearance of dark smut balls on infected panicle. The smut balls are orange or yellowish in colour that later turn to greenish dark balls (Baite *et al*. 2014). The disease reduced grain quality and caused yield loss varying from 0.5–75%, depending on the weather conditions during the crop-growing period (Osada 1995, Upadhyay and Singh 2013). Due to such intensity and loss of yield, the disease has gained importance in many rice-growing areas. Estimation of yield loss in rice will highlight the nature of the stress, the factors responsible for yield loss and possible interventions to prevent such loss in the future. Therefore, the objective of the investigation was to measure the false smut disease in Odisha and estimate the yield loss in the farmers' field. In the process, the possible factors of yield loss caused by false smut will be determined. The generated data will lay emphasis on the role of false smut in reducing the potential yield of different rice genotypes under field conditions.

MATERIALS AND METHODS

The survey was conducted randomly in different paddy fields of Odisha located at Kisan Nagar, Chandikhole, Jajpur, Badachana and Cuttack during *kharif* 2017, when the crop was at a maturity stage. These locations share similar climatic and farming conditions. The disease incidence assessment and yield loss were evaluated following standard procedure (Singh and Dube 1978). The data were collected on total number of plants, number of infected plants, disease incidence and severity, percentage of smut balls, weight of 50 healthy and smut panicles and finally yield loss assessment from a random sampling unit area of one square meter. Three replications were maintained for data

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collected from each genotype. The disease incidence was determined using the following formula;

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected tillers}}{\text{Total number of tillers}} \times 100$$

The disease severity is a quantitative measure of the number of smut ball in an infected panicle, which was calculated by using the formula;

$$\text{Disease severity (\%)} = \frac{\text{Number of smut balls per panicle}}{\text{Total number of grains per panicle}} \times 100$$

The yield loss was calculated following the formula given by Singh and Dube (1978);

$$\text{Yield loss (\%)} = \frac{100 \times \text{reduction in grain weight} \times \text{per cent infected tillers}}{\text{Grain weight of 50 healthy panicles} \times 100}$$

The percentage of chaffy grains was calculated by taking into account the filled and unfilled grains from the healthy and smut panicles for each genotype. The percent decrease in grain weight was calculated by taking into account the weight of 1000 filled grains from healthy and smut panicles in each genotype. The weather data of *kharif* 2017 was obtained from NRRI Weather Observatory, Cuttack.

Data analysis: Data were analyzed using IRRISTAT v.92-1 programme developed by International Rice Research Institute (IRRI), Philippines. It was also subjected to analysis of variance (ANOVA). Data in percentages were arcsine transformed before analysis. The means of treatment were compared by Duncan's multiple range test (DMRT) (Gomez and Gomez 1984). The data on weight of 50 panicles and chaffiness were analyzed using SAS software 9.3.

RESULTS AND DISCUSSION

Rice false smut is an emerging disease that generally infects few tillers and grains of the paddy plant. The typical false smut symptom was found in infected panicle and disease assessment was performed based on the number of smut balls present on the genotype. The data revealed that out of 20 genotypes surveyed only three genotypes were disease free while the remaining 17 genotypes showed 6.67–33.33% disease incidence and the disease severity ranged from 0.33–17.25% (Table 1). Three genotypes namely Mrunalini, CR Dhan 401 and Ranjit were free from infection which may be due to the presence of resistance genes or other factors. The disease incidence and severity were significantly highest in Pooja amongst all the genotypes and hence regarded as a highly susceptible genotype towards false smut. It may be due to lack of R-gene or that it is ineffective.

The highest disease incidence was observed in genotype Pooja (33.33%) followed by Varsha Dhan (16.67%) and Sarala (13.89%).The highest disease severity was observed in Pooja (17.25%) followed by Utkal Prava (10.46%) and Moti (8.89%). The disease incidence and severity are useful indicators of the nature of the disease. The disease incidence is a qualitative data because it only tells about whether the disease has occurred or not whereas, the disease severity is a quantitative data which indicates the proportion of infected area. We used a formula based on number of smut balls in an infected panicle for calculation of false smut severity, which is nothing but percentage smut ball and was shown in materials and methods section. The present formula exactly described the real situation of false smut severity in an infected panicle unlike the other formulae used by earlier workers (Singh and Dube 1978). Both, disease severity and yield loss are very important in the farmers' point of view because they have direct relevance to the crop production due to that stress. The false smut disease incidence in different rice genotypes was moderately high which had the potential to rise to an epidemic level if favourable environments are achieved. The disease incidence and severity values are slightly lower than earlier report by Baite *et al*. (2017), who observed disease incidence varying from 4.82–55.61% that may be attributed to presence of favourable weather conditions.

Temperature and humidity are two critical factors that influence disease incidence and severity because the pathogen is environment-sensitive and cause disease on susceptible host only when certain environment is achieved. Earlier

Table 1 False smut disease incidence and severity on 20 rice genotypes

Variety	Disease incidence (%)*	Disease severity (%)*
Gayatri	7.14 (15. 50) ^{h}	2.48 (9.06) ^{h}
Swarna sub1	9.71 (18.15) ^{f}	0.64 (4.59) ^{j}
Pooja	33.33 (35.26) ^{a}	17.25 (24.54) ^{a}
Sarala	13.89 (21.88) ^{c}	8.33 (16.77) ^{d}
Swad	8.33 (16.77) ^{g}	4.81 (12.67) ^{e}
CR Dhan 508	11.11 (19.47) ^{e}	0.33 (3.29) ^{m}
Varsha Dhan	16.67 (24.09) ^{b}	3.06 (10.07) ^{f}
Kala Champa	10.00 (18.43) ^{f}	0.88 (5.38) ^{i}
Sita	12.50 (20.70) ^{d}	0.43 (3.76) ^{l}
Swarna	7.14 (15. 50) ^{h}	0.84 (5.26) ^{i}
Mrunalini	0.00 (0.18) ^{j}	0.00 (0.18) ^{n}
Dharitri	7.14 (15. 50) ^{h}	2.81 (9.65) ^{g}
Luna Suvarna	10.00 (18.43) ^{f}	0.54 (4.21) ^{k}
Luna Sampad	11.11 (19.47) ^{e}	4.82 (12.68) ^{e}
CR Dhan 401	0.00 (0.18) ^{j}	0.00 (0.18) ^{n}
Ranjit	0.00 (0.18) ^{j}	0.00 (0.18) ^{n}
Moti	11.11 (19.46) ^{e}	8.89 (17.34) ^{c}
Durga	6.67 (14.97) ^{i}	0.51 (4.10) ^{k}
Utkal Prava	6.67 (14.97) ^{i}	10.46 (18.87) ^{b}
Padmini	10.00 (18.43) ^{f}	2.41 (8.93) ^{h}

Values are the mean of three replications. The numbers in the parenthesis are arcsine-transformed values. Means followed by a common letter are not significantly different at 5% level by DMRT.

Table 2 Chaffiness and yield loss due to false smut in different rice genotypes

Genotype	Weight of 50 panicles (g)		No. of grain/panicles		Chaffiness (%)		Yield loss (%)
	Healthy	Smut	Healthy	Smut	Healthy	Smut	
Gayatri	216.7	77	164	151	6.71	7.95	4.60 (12.38)[b]
Swarna sub1	155	125.5	179	156	2.79	35.26	1.85 (7.81)[k]
Pooja	123.5	118	135	131	8.15	23.66	1.48 (6.99)[m]
Sarala	229.5	192.5	236	168	12.29	44.05	2.24 (8.60)[h]
Swad	121	119.5	109	104	8.26	44.23	0.10 (1.81)[p]
CR Dhan 508	762.85	533	474	307	21.73	39.09	3.35 (10.54)[c]
Varsha Dhan	361.95	310.35	369	425	21.14	33.41	2.38 (8.87)[g]
Kala Champa	163.8	150.4	137	113	12.41	4.42	0.82 (5.19)[n]
Sita	123.9	90.15	179	231	14.53	20.35	3.40 (10.62)[c]
Swarna	160.55	115.7	221	119	38.91	8.40	2.00 (8.13)[j]
Mrunalini	117.7	0	123	0	24.39	0	0 (0.18)[q]
Dharitri	271.95	166.65	258	178	14.34	18.54	2.77 (9.58)[e]
Luna Suvarna	274.3	230.85	228	186	14.04	16.13	1.58 (7.22)[l]
Luna Sampad	223.2	170.65	194	166	7.73	26.51	2.62 (9.31)[f]
CR Dhan 401	368.7	0	322	0	37.89	0	0 (0.18)[q]
Ranjit	330.4	0	20	0	30.00	0	0 (0.18)[q]
Moti	273.8	147.1	151	45	5.96	35.56	5.14 (13.10)[a]
Durga	254	172.65	153	196	16.99	26.02	2.14 (8.41)[i]
Utkal Prava	206.9	184.15	245	153	22.45	70.59	0.73 (4.90)[o]
Padmini	183.75	128.3	122	83	9.84	0	3.02 (10.00)[d]

Values are the mean of three replications. The numbers in the parenthesis are arcsine-transformed values. Means followed by a common letter are not significantly different at 5% level by DMRT.

workers have reported disease incidence ranging between 16–40% in Chhattisgarh (Singh and Pophaly 2010), 2–75% in northern India (Ladhalakshmi *et al*. 2012) and 5–80% in Uttar Pradesh (Singh *et al*. 2014) which clearly shows that false smut incidence is dynamic and its intensity may increase or decrease abruptly without warning depending upon the weather parameters in a given point of time.The disease incidence and severity values fluctuates primarily due to the nature of the genotypes and environment and their interactions. The weight of 50 healthy panicles was relatively higher than the smut panicles in all genotypes. With the exceptions of three genotypes namely, Varsha Dhan, Sita and Durga, the number of grains were higher in healthy panicles compared to the diseased panicles (Table 2).

Similarly, the smut panicles in 17 of the rice genotypes had higher chaffiness percentage than the healthy panicles except for two genotypes namely, Kala Champa and Swarna. The maximum chaffiness percentage was found in Utkal Prava (70.59%) and minimum in Kala Champa (4.42%). The weight of panicles and the number of grains were reduced in diseased panicles. It might be due to the smut balls inducing the formation of sterile florets and drainage of food materials towards formation of smut balls, thereby, limiting/blocking the grains formation in the adjoining floret. Due to false smut infection, there is increased sterility of florets leading to chaffy grains that is in agreement with the findings of Hashioka (1971) and Atia (2004). Therefore, chaffiness of the grains in diseased panicles is a major factor contributing to yield loss in rice (Singh and Dube 1978, Anand *et al*. 1985, Atia 2004).

The disease reduced the weight of 50 panicles and 1000-grain weight while it increases the chaffy percentage of the infected panicles. The yield loss of 0.10–5% was observed and the mean yield loss was 2.06% (Table 2). The highest yield loss was observed in genotype Moti (5.14%) followed by Gayatri (4.60%), while the lowest yield loss was found in Swad (0.10%) followed by Utkal Prava (0.73%) and Kala Champa (0.82%). The yield loss for Pooja was 1.48% that is lower than the average loss. The rice flowering period and infection for *kharif* crop began from the month of September and continued until the grain maturity stages in December. The maximum temperatures during the four months (September-December in 2017) ranged between 27-32°C while the minimum temperature ranged from 14-26°C. The average relative humidity ranged from 74-82%. There was normal rainfall during September and October while it was scanty during November and December. There was low wind speed, evaporation rate and sunshine hours for the four months under consideration (Table 3).

Therefore, the yield loss due to false smut occurred due

Table 3 Weather parameters during *kharif* season of 2017 at Cuttack

Month	Tmax (°c)	Tmin (°c)	Rainfall (mm)	RH (%)	Windspeed (kmph)	Evaporation (mm)	Sunshine (Hrs)
September	32.66	26.63	224.00	82.41	1.00	3.19	3.57
October	31.54	25.69	225.00	82.75	1.39	2.62	4.25
November	27.50	19.02	47.00	74.55	1.88	1.82	4.89
December	27.16	14.35	17.00	82.00	1.01	0.99	3.18

Tmax= maximum temperature, Tmin= minimum temperature, RH= Relative humidity

to reduction of panicle weight, reduction in number of grain, grain weight and increase in number of chaffy grain in smut panicles as is evident from the observed data. The yield loss due to false smut is exacerbated by the favourable weather conditions during the latter stage of paddy. Interestingly, the genotype which was considered to be very susceptible to false smut (Pooja) did not suffer much yield loss because the genotype was tolerant to false smut. This might be the reason that in spite of being susceptible, Pooja continues to be grown and cultivated by a larger number of farmers in Odisha and neighbouring states. Earlier workers reported yield losses of rice ranging from 0.20– 44.37% (Singh and Dube 1978), 7–75% (Agarwal and Verma 1978), 1.01–10.91 % (Atia 2004), 0.5–75% (Upadhyay and Singh 2013) and 0.09–4.25% (Muniraju *et al*. 2017). Such variations might be due to the interactions of prevailing environmental factors and genotypes in a location.

Pooja was significantly higher in terms of false smut disease incidence and severity among all the genotypes, which indicated that it is highly susceptible to false smut. The genotypes having better resistance to the disease may be promoted among farmers for large-scale cultivation provided other agronomic features are satisfied. In general, it is imperative to protect the plant from false smut infection by proper selection of rice genotypes, early planting, and use of bio-agents, preventive chemical spray or use of resistant genotype in order to reduce the losses caused by rice false smut. The yield loss data indicated that the false smut is an emerging problem for rice production and therefore proactive measures must be applied to prevent further losses.

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