Indian Journal of Agricultural Sciences **88** (1): 132–7, January 2018/Article

Management of paddy bunt (*Tilletia barclayana*) through mechanical seed processing

ASHWANI KUMAR[1] and ANUJA GUPTA[2]

ICAR-Indian Agricultural Research Institute, Regional Station, Karnal, Haryana 132 001

Received: 09 May 2017; Accepted: 29 August 2017

ABSTRACT

Paddy bunt or kernel smut of rice caused by *Tilletia barclayana* (Syn. *Neovossia barclayana*, *N. horrida*) is major disease of rice growing countries. Seeds of two lots of Pusa 44 variety produced during *kharif* 2014 and one lot produced during *kharif* 2015 were processed. Pre-cleaner and screen grader removed 44.7, 34.8 and 42.2% of total bunt infected seed present in the three seed lots and reduced bunt infection from 1.32 to 0.73, 1.58 to 1.03 and 3.05 to 1.76%, respectively. Eighteen combination treatments comprising of three deck slopes (S_1- 2.5^0, S_2- 2.0^0, S_3- 1.5^0), three feedings (F_1- 9 kg, F_2- 12 kg, F_3- 15 kg per minute) and two output settings (O_1- 30cm deck width, O_2- 40cm deck width) of specific gravity separator were studied with an objective of getting maximum bunt free seed per unit of time. Maximum seed recovery (13.27 and 13.31 and 13.60 kg/minute) and bunt infection in final product (0.44, 0.41 and 0.46%) with 89.1, 89.7 and 92.3% recovery efficiency was obtained by the treatment $S_3F_3O_2$ (slope of deck 1.5^0, feeding 15 kg/minute, output deck width 40 cm) in the three seed lots. Thus, mechanical processing reduced bunt infection by more than 65%, depending on the intensity of infection, as well as increased seed quality i.e. seed germination improved by 6.5% and physical purity by 5.34%.

Key words: Management, Mechanical processing, Paddy bunt

Paddy bunt also known as kernel smut of rice, a designated disease, caused by *Tilletia barclayana* (Bref.) Sacc. & Syd. (Syn. *T. horrida* Tak., *Neovossia barclayana* Bref., *N. horrida* (Tak.) Padw. and Khan) is prevalent in all the major rice growing countries (CMI 1976, Ou 1985, Dorofeva *et al*. 1993, Santosh *et al*. 1996 and Moletti *et al*. 1996). In India, the disease was reported for the first time by Butler in 1913. Since then, it has spread to all the rice growing states of the country (Sharma 2001). The economic importance of the disease has been highlighted by various workers from many countries where the losses have been reported to be ranging from 2-63% (Sharma 2001). The disease was considered to be of minor importance, but assumed serious proportions around 1990 when about 13.8% of the total graded seed was rejected by the Seed Certification Agency on account of its failure to meet the minimum seed certification for this disease (Sharma and Gill 1997). In the past two decades, due to changed climatic conditions, cropping systems and enhanced inputs, the disease has assumed serious proportion in Haryana and Punjab resulting in large scale rejection of quality seed for not meeting the minimum permissible standards of 0.5 and 0.1% for certified and foundation seeds, respectively (Sharma and Chahal 1996, Sharma *et al*. 1999). Bunt infected grain shows no symptoms until near maturity. The symptoms appear first as minute black streaks bursting through the glumes at the time of ripening and can be seen in the field only at the time of crop maturity. The disease is not easily detected in the field and for this the seed must be threshed and examined. Paddy bunt being a designated disease and bunt pathogen being seed, soil and air borne, therefore, post harvest management of paddy bunt through mechanical processing was undertaken to recover high quality healthy seed.

MATERIALS AND METHODS

Seeds of two lots of Pusa 44 variety (10000 kg of breeder and 50000 kg of truthfully labeled (TL) seed) grown at ICAR-Indian Agricultural Research Institute, Regional Station, Karnal during *kharif* 2014 and one lot of same variety (50000 kg of TL seed) produced during *kharif* 2015 were processed in Nippon Sharyo (Japan) make processing plant of one tonne per hour capacity. The average moisture content of the wheat seed determined as per ISTA rules (1993) were 13.2, 12.9 and 13.3%, respectively and hence seed drying was not considered necessary for processing.

The processing line comprised of seed pre-cleaner-cum-grader, screen grader, indent cylinder grader in bypassed mode and specific gravity separator. Air screen machines (pre-cleaner and screen grader) were equipped with feed control, aspiration system, scalping screen, and grading screen. Top and bottom sieves of air screen machines was 3.2 mm (oblong) and 2.1 mm (oblong), respectively. The essential parts of specific gravity separator were an adjustable porous deck, fan system that forces air through

[1](e mail: ashakmash@gmail.com)

the porous deck, assemblies that oscillate and incline the deck. The slope or inclination of deck, feeding and output were adjusted for better separations of low density diseased seeds from the lot. A total of 18 combinations, comprising of three deck slopes (S_1- 2.5^0, S_2- 2.0^0, S_3- 1.5^0), three feedings (F_1- 9 kg, F_2- 12 kg, F_3- 15 kg per minute) and two output settings (O_1- 30 cm deck width, O_2- 40 cm deck width) of specific gravity separator were studied with an objective of getting maximum bunt free seed per unit of time.

Ten samples, weighing 500 g each, were drawn for quality assessment at different stages, viz. unprocessed, product outlets of pre-cleaner, screen grader and specific gravity separator at intervals of 10 minutes. These 10 primary samples collected from each stage were mixed separately using mixer and then divided by seed divider. Three replications weighing 1.0 kg each were drawn from the mixture for each stage, and classified as representative samples. These representative samples were used for physical purity, germination, test weight, germination index and vigour index evaluation as per ISTA rules (1999). The laboratory-based study on physical purity was measured using two replications of 50 g each with Complete Randomized Design. Pure seed, inert matter and other crops seed were separated using purity board and physical purity was calculated on weight basis (Agrawal 1993). Four replications of hundred seeds each were kept between wet paper towels in the germinator for 14 days at 25°C and 95% RH. The number of normal seedlings, abnormal seedlings and dead seeds were counted and recorded. Germination per cent was expressed on the basis of normal seedlings. The 1000-seed weight of each sample was measured. Root and shoot length of ten normal seedlings was measured and dried at 80°C in oven for 24 h to get dry weight. Seed vigour index - I and II were derived by multiplying per cent germination with total seedling length (cm) and dry weight of seedlings (g), respectively (Gupta 1993, Abdul-Baki and Anderson 1973). For output efficiency of the specific gravity separator, three samples were taken from the final product outlet to calculate the amount of seed cleaned in one minute. Two samples of 100 g each were drawn from product and reject outlets of specific gravity separator to study paddy bunt (PB) infection which was detected by sodium hydroxide seed soak technique (Agarwal and Srivastava 1981). In this technique, paddy seeds were soaked for 24 h in 0.2% solution of NaOH at 20-25°C. After decanting the solution next day, the seed was spread on a white blotter sheet to remove excess moisture. On examination, the bunt infected seeds appear shiny jet black in colour. The infection of bunt was confirmed by rupturing each discoloured seed in a drop of water with a fine needle when a stream of bunt spores was released. Bunt infection was calculated on number basis and expressed in percentage. Thereafter, recovery efficiency was computed using the following equation:

$$\text{Recovery efficiency (\%)} = \frac{\text{Final output (100 – Bunt infected seed (\%) in final output)}}{\text{Feeding (100 – Bunt infected seed (\%) in feeding)}} \times 100$$

Data were subjected to analysis of variance using completely randomized design (Gomez and Gomez 1984). Critical differences at 5% probability level were calculated and used for interpretation.

RESULTS AND DISCUSSION

The intensity of bunt disease on paddy seed was variable and very much dependent on environmental conditions at the time of anthesis and it also affected the size and density of seed. The portion of paddy seed affected with *T. barclayana* was transformed into teliospores of the fungus and looked like black powder on examination. The infection of individual kernels varied from small points of infection to completely bunted kernels. The embryo was largely undamaged except when infection was severe. Severely damaged grains (Fig 1) were identified very easily since the endosperm tissues are replaced with spores. The seeds with small lesions produce normal seedlings, whereas those with severe infection had poor germination and produced weak, distorted seedlings. Paddy bunt infection has been classified into three categories (Fig 1) based on the intensity of the disease on the seed, healthy (0% infection), partial (1-75% infection) and full (76-100% infection).

Bunt infection in raw seed (unprocessed) was higher than the permissible limit in all the three seed lots (Table 1) due to cooler temperature and well distributed rainfall during anthesis stage. A temperature range of 25-30°C, relative humidity of 85% or more and intermittent showers at ear emergence stage are reported to influence the disease development of paddy bunt (Singh and Pavgi 1970, Whitney and Freideriksen 1975, Cartwright 1997). It has already been highlighted that it is not the amount of rainfall but the distribution of rainfall, which accounts for the bunt outbreaks. More rainfall occurring for a short

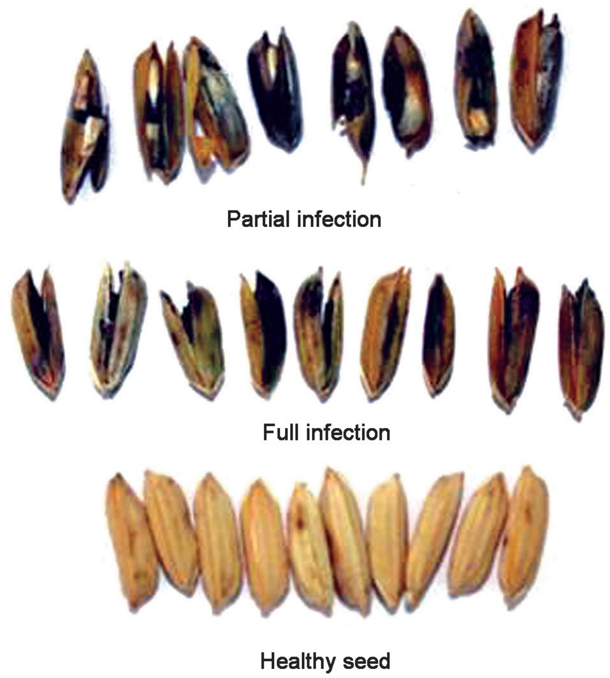

Fig 1 Bunt intensity

period may not be of much significance for the disease development, but uniformly distributed rainfall for longer period from boot stage to panicle emergence stage enhanced the probability of disease occurrence (Sharma *et al.* 2010).

Total bunt infection in the unprocessed seed lot was 1.32 and 1.58 in breeder and TL seed lots of paddy cv. Pusa 44 produced during *kharif* 2014 and 3.05% in TL seed lot of paddy cv. Pusa 44 produced during *kharif* 2015 (Table 1). The bunt infection reduced from 1.32 to 0.73, 1.58 to 1.03 and 3.05 to 1.76% in the three seed lots, respectively.

Table 1 Percent infection of paddy bunt at different stages of processing

Year/Lot	Unpro-cessed	Pre-cleaned	Screen graded	Rainfall 100-120 DAS (mm)	Average temp. (°C)	
					Max.	Min.
2014/ Breeder	1.32	1.02	0.73	215.4 (6*)	34.3	20.6
2014/ Labeled	1.58	1.29	1.03	215.4 (6*)	34.3	20.6
2015/ Labeled	3.05	2.31	1.76	170.4 (7*)	35.7	18.8

*Effective rainy days

Pre-cleaner removed 22.7, 18.4 and 24.3% and screen grader removed 28.4, 20.2 and 23.7% of total bunt infected seed present in the three seed lots, respectively. Thus, it was observed that pre-cleaner and screen grader together removed 44.7, 34.8 and 42.2% of the total PB infected seed present in the seed lots.

Though the bunt infection reduced after passing through pre-cleaner and screen grader machines, but it was still higher than the permissible limit of 0.1 and 0.5% in case of foundation and certified seed, respectively. Specific gravity separator was observed to further improve the seed quality by removing bunt infected seed in 18 treatment combinations used in this study for the three seed lots. Minimum bunt infection in the final product (0.30, 0.32 and 0.33%) was obtained in $S_3F_2O_1$ treatment (slope of deck 1.5°, feeding 12 kg/minute, output deck width 30 cm) but this treatment gave low bunt free final product (10.14, 10.20 and 9.68 kg/minute) with low recovery efficiency of 85.1, 85.9 and 82.1% in the three seed lots, respectively as against $S_3F_3O_2$ treatment (slope of deck 1.5°, feeding 15 kg/minute, output deck width 40 cm) which gave maximum bunt free seed recovery (13.27, 13.31 and 13.60 kg/minute) with maximum recovery efficiency of 89.1, 89.7 and 92.3% in the three seed lots, respectively. The per cent infection of paddy bunt

Table 2 Recovery efficiency of paddy bunt free seed by specific gravity separation during 2014 (2 lots) and 2015

Treatment	Feed/minute (kg)	Paddy bunt infection (%) in final output			Paddy bunt free final output/minute (kg)			Recovery efficiency (%)		
	SGS	2014 Breeder	2014 Labeled	2015 Labeled	2014 Breeder	2014 Labeled	2015 Labeled	2014 Breeder	2014 Labeled	2015 Labeled
$S_1F_1O_1$	9.00	0.50	0.47	0.89	3.88	3.85	3.63	43.4	43.2	41.1
$S_1F_1O_2$	9.00	0.50	0.64	1.16	4.34	4.47	4.32	48.6	50.2	48.8
$S_1F_2O_1$	12.00	0.53	0.62	0.79	5.01	5.57	7.24	42.0	46.9	61.4
$S_1F_2O_2$	12.00	0.48	0.57	1.11	5.44	6.30	8.83	45.7	53.0	74.9
$S_1F_3O_1$	15.00	0.44	0.58	1.08	7.96	8.42	9.89	53.5	56.7	67.1
$S_1F_3O_2$	15.00	0.51	0.63	1.17	9.12	9.61	11.46	61.2	64.7	77.8
Mean	12.00	0.49	0.58	1.03	5.96	6.37	7.56	49.08	52.45	61.87
$S_2F_1O_1$	9.00	0.48	0.57	0.74	6.63	6.50	5.96	74.3	72.9	67.4
$S_2F_1O_2$	9.00	0.49	0.57	0.80	7.53	7.49	6.61	84.3	84.1	74.8
$S_2F_2O_1$	12.00	0.51	0.53	0.63	8.49	8.36	8.35	71.3	70.4	70.8
$S_2F_2O_2$	12.00	0.41	0.54	0.89	9.26	9.58	9.45	77.8	80.7	80.1
$S_2F_3O_1$	15.00	0.47	0.55	0.65	10.98	10.61	11.79	73.7	71.5	80.0
$S_2F_3O_2$	15.00	0.52	0.54	0.72	12.04	12.33	12.64	80.8	83.1	85.8
Mean	12.00	0.48	0.55	0.74	9.16	9.14	9.13	77.02	77.10	76.48
$S_3F_1O_1$	9.00	0.37	0.45	0.53	8.00	8.26	8.31	89.6	92.8	93.9
$S_3F_1O_2$	9.00	0.46	0.51	0.46	8.53	8.72	8.49	95.5	97.9	96.1
$S_3F_2O_1$	12.00	0.30	0.32	0.33	10.14	10.20	9.68	85.1	85.9	82.1
$S_3F_2O_2$	12.00	0.35	0.43	0.52	10.60	10.55	10.38	88.9	88.9	88.0
$S_3F_3O_1$	15.00	0.45	0.35	0.39	12.34	12.46	12.38	82.9	83.9	84.0
$S_3F_3O_2$	15.00	0.44	0.41	0.46	13.27	13.31	13.60	89.1	89.7	92.3
Mean	12.00	0.40	0.41	0.45	10.48	10.58	10.48	88.52	89.84	89.43

SGS= Specific gravity separator

in $S_3F_3O_2$ treatment was 0.44, 0.41 and 0.46% in the three seed lots, respectively, within the certification standards of 0.5% for the certified seed. Similar results were obtained for management of Karnal bunt disease in wheat by Kumar *et al.* (2015).

Statistical analysis of the data revealed that the three slopes of the deck of specific gravity separator (1.5°, 2.0° and 2.5°) were significantly different with respect to per cent paddy bunt infection in the final product, the amount of final output/minute and per cent recovery efficiency of good quality product (Table 3). Minimum bunt infection in the final product (0.40, 0.41 and 0.45%) was obtained in slope 3 (1.5°) in all the three seed lots, respectively. Minimum slope of the deck (S_1=1.5°) also gave maximum recovery of the bunt free final product (10.48, 10.58 and 10.48 kg/minute) with maximum recovery efficiency of 88.44, 89.84 and 89.43% in the three seed lots, respectively. The per cent bunt infection in the final product was statistically non-significant in the three feedings to the machine and the two deck widths. Amongst the three feedings, F_3 of 15 kg/minute gave maximum bunt free final product (10.95, 11.12 and 11.96 kg/minute) with maximum recovery efficiency of 73.56, 74.92 and 81.18% in the three seed lots, respectively. The two output deck widths were statistically different from each other and deck width of 40 cm gave maximum bunt free final product (8.90, 9.15 and 9.53 kg/minute) with maximum recovery efficiency of 74.66, 76.91 and 79.86% in the three seed lots, respectively.

With increase in slope of the deck, paddy bunt infection in the final output increased but final output per minute and recovery efficiency decreased significantly in all the seed lots. On the other hand, increased feeding to specific gravity separator led to significant increase in final output per minute and decrease in recovery efficiency but paddy bunt infection in the final output was at par in all the feedings. Output treatments were at par for paddy bunt infection in the final output but final output per minute and recovery efficiency reduced significantly with reduction in output collection deck width, hence O_2 treatment (40 cm deck width) was better than O_1 treatment (30 cm deck width).

Germination and physical purity of unprocessed seed was 83.50% and 93.72%, respectively for the three seed lots (Table 4); which were lower than the Indian Minimum Seed Certification Standards of 80% and 98%, respectively (Trivedi and Gunasekaran 2013). In the present study, out of the total of 110000 kg seed processed, 91630 kg (83.30%) seed fulfilling Indian Minimum Seed Certification Standards of quality seed was received at the product outlet after processing. The seed lot which was below minimum standards of physical purity and germination turned to an acceptable lot with 99.06% physical purity and 90.0% germination. Physical purity after specific gravity separation was significantly higher than that of pre-cleaned and graded seed lot. This shows necessity of all the three processing operations in processing of paddy seed for higher seed quality. Specific gravity separator alone improved germination by 4.0%, followed by screen grader (1.5%) and pre-cleaner (1.0%). Germination was at par amongst the processing machines, which reflected that the original seed lot had less proportion of seed with poor germination. Moreover, all the three machines together improved the seed lot germination by 6.5% and physical purity by 5.34%. Similar results were observed in wheat by earlier researchers (Sinha *et al*. 2002, Doshi *et al*. 2013).

Test weight was also found to be significantly higher in the seed lot after gravity separation (Table 4). Maximum rise in test weight was observed after passing through specific gravity separator (0.8 g), followed by screen grader (0.68 g) and pre-cleaner (0.86 g). This implied that gravity separation had a positive effect on the seed test weight. Present results confirmed the earlier findings of Sinha *et al*. (2002). Germination, vigour index-I and vigour index-II at

Table 3 Mean recovery efficiency of paddy bunt free seed by specific gravity separation during 2014 (2 lots) and 2015.

Treatment	Paddy bunt infection in final output (%)			Final output/minute (kg)			Recovery efficiency (%)		
	2014 Breeder	2014 Labeled	2015 Labeled	2014 Breeder	2014 Labeled	2015 Labeled	2014 Breeder	2014 Labeled	2015 Labeled
Slope 1 (2.50)	0.49	0.58	1.03	5.96	6.37	7.56	49.13	52.45	61.87
Slope 2 (20)	0.48	0.55	0.74	9.16	9.14	9.13	77.02	77.10	76.48
Slope 3 (1.50)	0.40	0.41	0.45	10.48	10.58	10.48	88.44	89.84	89.43
Feeding 1 (9 kg/min)	0.47	0.54	0.73	6.49	6.55	6.22	72.60	73.52	70.35
Feeding 2 (12 kg/min)	0.43	0.5	0.74	8.15	8.43	8.99	68.43	70.95	76.25
Feeding 3 (15 kg/min)	0.47	0.51	0.73	10.95	11.12	11.96	73.56	74.92	81.18
Output 1 from 30 cm deck width	0.45	0.49	0.67	8.16	8.25	8.58	68.40	69.34	71.99
Output 2 from 40 cm deck width	0.46	0.54	0.81	8.90	9.15	9.53	74.66	76.91	79.86
CD (P=0.05) for Slope	0.07	0.11	0.23	1.21	1.25	1.13	5.36	5.12	5.27
CD (P=0.05) for Feeding	NS	NS	NS	1.79	1.84	1.81	NS	NS	2.29
CD (P=0.05) for Output	NS	NS	0.12	0.67	0.73	0.79	2.38	2.82	2.14
CD (P=0.05) for Interactions	NS	NS	NS	1.01	1.12	1.08	1.64	1.77	2.15

Table 4 Mean values of different quality parameters at different stages of processing for three seed lots of paddy during *kharif* 2014 and 2015

Stage	Physical purity (%)	Germ. (%)	Test weight (g)	Vigour index I	Vigour index II
Unprocessed	93.72	83.5	22.33	130.29	74.72
Pre-cleaned	96.24	84.5	23.19	141.69	83.74
Screen graded	98.01	86.0	23.87	158.44	89.13
Specific gravity separated	99.06	90.0	24.67	166.39	99.89
Rejected by SGS	59.32	62.5	18.37	91.26	53.63
CD (P=0.05)	0.98	5.23	0.39	26.53	20.43

different stages of processing were found to be statistically at par, and remarkable improvement in desired quality parameters of the seed lot was observed through processing (Table 4). All the quality parameters of seed improved significantly after specific gravity separation as against raw (unprocessed) seed thereby indicating that the size and density of seed are important factors for determining seed quality and importance of gravity upgradation in improving vigour of the seed lot. Seed quality parameters of the rejected component of the specific gravity separator were far below the standards, and were also inferior to the unprocessed seed lot at each stage. These results thus showed positive impact of separation process in all the three machines and emphasized the necessity of processing.

Seed germination in partial and full infected seed was 47.3 and 12.5%, respectively as against 90.0% in healthy seed (Table 5). There was 23.04 and 48.21% loss in seed weight in partial and full infected seed as against healthy seed. Sharma and Chahal (1996) also found that infection grades of seeds were negatively correlated with the growth parameters of the seed as loss in seed germination, seedling length and dry weight. Bansal *et al.* (1984) also reported reduction in 1000-grain weight ranging from 4.5 to 52.3% depending on severity of Karnal bunt infection in wheat. Increase in disease severity resulted in proportional decrease in seed weight, germination and vigour.

Table 5 Effect of paddy bunt infection on seed quality parameters

Paddy bunt infection	Test weight (g)	Loss in seed weight over healthy seeds (%)	Germination (%)
Healthy	23.48	-	89.0
Partial	18.07	23.04	47.3
Full	12.16	48.21	12.5

Healthy=0% infection, Partial=1-75% infection, Full=76-100% infection

Table 6 Intensity of paddy bunt infection (%) at different stages of processing

Year/Seed lot	Unpro-cessed		Pre-cleaned		Screen graded		Specific gravity separated	
	Partial	Full	Partial	Full	Partial	Full	Partial	Full
2014/ Breeder	37	63	45	55	67	33	99	01
2014/ Labeled	46	54	55	45	73	27	100	00
2015/ Labeled	34	66	51	49	71	29	99	01

Partial and full infections in unprocessed seed was 37, 46 and 34% and 63, 54 and 66% in the three seed lots, respectively (Table 6). However, after specific gravity separation, partial infection increased and full infection decreased. Similarly, there was decrease in full infected seeds and increase in partial infected seeds during pre cleaning and screen grading processes. Partial infected seeds increased and full infected seeds decreased with each processing stage.

Hence, the study revealed that mechanical processing reduced paddy bunt infection by more than 65%, depending on the intensity of infection. It not only increased the grain quality making it fit for human consumption but also enhanced seed quality (seed germination improved by 6.5% and physical purity by 5.34%). Paddy bunt being a seed borne disease, its management through mechanical processing will increase the availability of healthy seed in the seed multiplication chain.

REFERENCES

Agarwal V K and Srivastava A K. 1981. A simpler technique for routine examination of rice seed lots for rice bunt. *Seed Technology News* **11(3)**: 1.

Abdul-Baki A A and Anderson J D. 1973. Vigour determination in soybean seed by multiple criteria. *Crop Science* **13(6)**: 630–3.

Agrawal R L. 1993. Physical purity analysis. (*In*) *Handbook of Seed Testing,* p 340. Agrawal P K (Ed). Deptt. of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi.

Bansal R, Singh D V and Joshi L M. 1984. Effect of Karnal bunt pathogen (*Neovossia indica* (Mitra) Mundkur) on weight and viability of wheat seed. *Indian Journal of Agricultural Sciences* **54**: 663–6.

Cartwright R D, Ross W J, Parsons C E, Lee F N, Eason R and Templeton G E. 1997. Artificial inoculation of kernel smut of rice in Arkansas. *Research Series of Arkansas Agriculture Experiment Station* No. **456:** 90–3.

CMI. 1976. *Distribution Maps of Plant Diseases*, No. 75, 3rd edn., Issue I, IV. CAB International Mycological Institute, New, UK.

Dorofeeva L L, Sizova T P and Shapovalova P A. 1993. Phytopathological condition of rice plantation in central Asia. *Mikolojiya-I-Fitopathologiya* **27:** 62–6.

Doshi J S, Patel V B, Patel J B and Patel J A. 2013. Quantification of quality improvement in wheat seed processing. *Journal of Agricultural Engineering* **50(4)**: 83–6.

Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research*, 2nd edn. An IRRI Book, John Wiley & Sons, New York.

Gupta P C. 1993. Seed Vigour Testing. (*In*) *Handbook of Seed Testing*, 340 p. Agrawal P K (Ed). Department of Agriculture and Cooperation, Ministry of Agriculture, Government of

India, New Delhi.
ISTA. 1993. International rules for seed testing. *Seed Science and Technology (supplement)* **21:** 288.
ISTA. 1999. International rules for seed testing. *Seed Science & Technology (supplement)* **27:** 1–335.
Kumar A, Gupta A, Atwal S S, Maheshwari V K and Singh C B. 2015. Post harvest management of Karnal bunt, a quarantine disease, in wheat. *Plant Pathology Journal* **14(1)**: 23–30.
Moletti M, Guidicia M L and Villa B. 1996. Caryopsis smut: a new disease of rice in Italy. *Informatore Agrario*. **52:** 51–5.
Ou S H. (1985). Rice Diseases. CAB IMI, Kew, Survey, U.K.
Santosh Dos A A and Figueiredi M B. 1996. Occurrence of rice kernel smut (*Tilletia barclayana*) in Ceara, Brazil. *Fitopatologia-Brasikria* **21**: 96.
Sharma R C. 2001. Kernel smut of paddy and its control. (*In*) *Seed Technology and Seed Pathology*, p 498. Singh Tribhuwan and Aggarwal Kailash (Eds). Pointer Publishers, Jaipur.
Sharma R C and Chahal H S. 1996. Seed health studies on parental lines of hybrid rice. *Seed Research* **24(2):** 145–50.
Sharma R C and Gill S S. 1997. Status of kernel smut of paddy in Punjab and its control. *Seed Research* **25(1)**: 68–73.
Sharma R C, Gill S S, Joshi D P, Allah Rang, Bassi Geeta and Bharaj T S. 1999. Kernel smut – a major constraint on hybrid seed production of rice and its remedial measures. *Seed Research* **27:** 82–90.
Sharma R C, Gill K K and Sharma Indu. 2010. Forecasting paddy bunt disease in Punjab- An agrometeriological approach. *Indian Phytopathology* **63(1)**: 16–20.
Singh R A and Pavgi M S. 1970. Varietal reaction and resistance to kernel bunt of rice. *Indian Phytopathology* **23:** 51–3.
Sinha J P, Vishwakarma M K, Atwal S S and Sinha S N. 2002. Quality improvement in rice (*Oryza sativa*) seed through mechanical seed processing. *Indian Journal of Agricultural Sciences* **72(11)**: 643–7.
Trivedi R K and Gunasekaran M. 2013. *Indian Minimum Seed Certification Standards.* The Central Seed Certification Board, Department of Agriculture and Co-operation Ministry of Agriculture Government of India, New Delhi, p 605.
Whitney N G and Freideriksen R A. 1975. Kernel smut of rice. *Texas Agriculture Experiment Station MP.* 1231.