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Variation in the stored grain pest *Sitotroga cerealella* (Olivier) infestation at low and high moisture storage conditions among some indigenous rice genotypes of West Bengal

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Abstract: The food security programme is negatively impacted by postharvest losses (PHLs). In terms of providing food for a nation, proper grain postharvest (PHV) storage is more crucial than intense and widespread farming. Reducing post-harvest losses of food crops is essential to raising agricultural production sustainably. Each year, insects and diseases destroy or harm a fifth or more of stored food grains in many regions of the world. The angoumois grain moth, *Sitotroga cerealella* (Oliver), is a major stored grain pest of rice. Control of *Sitotroga cerealella* (Olivier) is still much dependent on the use of toxic chemicals though there is a chance of residual toxicity to the non-target organism. Rice, wheat, and corn are just a few examples of grains that are crucial to the economic stability of many nations. Cereals like rice, wheat and corn play an important role in the economic stability of many countries. Some indigenous rice varieties of rice are reported to be tolerant of this pest. This study was undertaken to identify West Bengal indigenous rice varieties susceptible to the stored grain pest *S. cerealella* infestation at low and high moisture storage conditions.

Introduction

In developing nations, postharvest losses (PHLs) of stored crops are a widespread issue. PHLs harm the food security programme. In order to ensure that a country has enough food, proper grain postharvest storage is more crucial than intense and widespread farming (Tadesse, 2020). Rice, wheat, and corn are just a few examples of grains that are crucial to the economic stability of many nations. The World Bank estimates that India's post-harvest losses equal 12 to 16 million metric tonnes of food grains annually, enough to feed one-third of the country's impoverished. These losses have a monetary value of more than Rs, 50,000 crores yearly (Singh, 2010). Making sure there's enough food for the world's expanding population is a major worldwide concern. There are several investigations into the factors that contribute towards post-harvest loss in Rice. In a 2021 study published in the Sustainability Journal, Qu and colleagues argued that "lack of knowledge, inappropriate farming techniques, poor infrastructure, and improper harvest management procedures" were major causes of rice harvest losses (Qu et al., 2021). Reducing postharvest losses (PHLs) of food crops is essential to enhancing agricultural productivity in a sustainable manner (Stathers et al., 2020).

Postharvest losses (PHLs) and insect infestation

It is estimated that in India, 10% of all grains are lost during the post-harvest processing and short-term storage processes (Kumar, 2002). Postharvest loss refers to the decline in yield and quality that occurs between harvest and final consumption. Annually, insects and illnesses destroy or severely damage at least one-fifth of the world's stored food grains. Hall (1990) estimates a yearly loss of 130 million tonnes of stored grain owing to insect infestations. Among the many pests of rice in storage is *S.*

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cerealella, sometimes known as the angoumois grain moth. *S. cerealella* (Olivier) attacks rice grain in the field and storage, causing an estimated overall yield loss of upto 30% (Singh and Benazet, 1975). Infested grain in storage has a sickening taste and smell, making it unpalatable. Only whole grain is attacked, so other grain products are safe. *S. cerealella* (Olivier) is a cosmopolitan pest, a strong flier who flies to the field of ripening grain for initial egg laying. The field level damage tends to be 10 times higher in the ears in the field, which is close to any storage facility (Weston, 1997). The hatching of eggs depends upon the relative humidity and grain moisture (Warren, 1956).

Storage conditions and use of Tolerant rice varieties for the control of *Sitotroga cerealella* (Olivier)

Apart from the inherent tolerance of varieties, some researchers have shown that storage conditions are also very important for post-harvest loss (Parfitt et al., 2010; Majumder et al., 2016). Control of *S. cerealella* (Olivier) is still much dependent on the use of toxic chemicals though there is a chance of residual toxicity to the non-target organism. Many scientists in different countries have tried to identify tolerant varieties so that chemical control could be lessened (Aruna et al., 2009; Gerding and Heinrich, 1986; Gillani and Irshad, 1990; Prakash and Rao, 1993; Ashamo, 2010; Rizwana et al., 2011). The impact of such tolerant varieties could be dramatic in developing countries, where grain infestations are most common and harmful and where surging populations require affordable food (Bergyinson and Garcia-Lara, 2004). Little work has been done in screening West Bengal indigenous rice varieties for tolerance against *S. cerealella* (Olivier). When identified, the tolerant West Bengal rice landraces could be used as parents in future breeding programmes for *S. cerealella* (Olivier) tolerance.

Objective of the study

The primary objective of this analysis was to explore whether there are any differences in the infestation of the stored grain pest *S. cerealella* (Olivier) at low and high moisture storage conditions among indigenous rice varieties of West Bengal. With the results from this study, it would be possible to identify the storage conditions of West Bengal indigenous rice varieties, which could contribute to tolerance to *S. cerealella* (Olivier) infestation. Another objective was to evaluate the tolerance to *Sitotroga cerealella* (Olivier) in the different rice varieties. Grain moisture content in both low and high humidity storage conditions and corresponding *S. cerealella* infestation among the rice varieties was investigated.

Materials and Methods

Plant Materials

A total of 30 rice genotypes were used for this study. 17 West Bengal landraces (both aromatic and non-aromatic) were collected from various areas around the state of West Bengal, India and kept at the Bose Institute's Madhyamgram Experimental Farm. The rice genotypes included aromatic rice landrace of West Bengal (A WBL) and non-aromatic rice landrace of west Bengal (NA WBL). The non-aromatic rice lines (NA) included high-yielding varieties used in international check (HYV NA) and also indigenous (of Indian origin) high-yielding (HYV INA) cultivars. Indigenous aromatic (IA), Traditional Basmati (TB) and Evolved Basmati (EB) were taken as aromatic checks. The name of the cultivars used in this study with origin and place of adaptation are given in Table 1.

Experimental setup

Triplicates of 40 plants each were used in the Randomised Block Design (RBD) to grow the different rice genotypes. On the last week of June, seeds were sowed in the seedbed, and after 30 days, one robust seedling or hill was transplanted at a row x plant spacing of 25cm x 15cm. The usual agronomic procedures were used.

Assessment of Natural Infestation at low and high grain moisture conditions

Thirty rice genotypes, of which 17 were West Bengal landraces, were cultivated at Bose Institute Experimental Farm, Madhyamgram, West Bengal, India. The maturity time of grains of each cultivar was taken. The cultivation plot was so chosen that it was less than 500m away from the storage facility and the ears were allowed to be infested by *Sitotroga cerealella* (Olivier) in the field without any insecticide application during maturity. Soon after harvest, the grains were dried, moisture content measured by METREX grain moisture meter and kept in close-mouth paper bags containing 100 gms of seed in three replication in a storage facility highly infested with *S. cerealella* (Olivier) at 35±3^{0}C and 55±5% RH. After the winter months (45 to 60 days), the bags were opened and the emergence of the adult moths was noticed. Three aliquots were collected from each bag from 1 cm X 1 cm surface of the grain and the moisture condition was measured. Damaged grains were counted under a microscope in all the aliquots of the cultivars and the families. The apparently non-infected grains were tested by pres-

Table 1. Names, areas of adaption, and origin for each of the thirty rice genotypes that were studied.

Sl. No	Genotypes	Place of adaptation/source	Origin	Type of cultivar
1	Kajaldekhi	Cooch Behar	CL, SF	NA WBL
2	Chottonunia	Cooch Behar	CL SF	NA WBL
3	Bochi	Cooch Behar	CL, SF	NA WBL
4	Joshoa	Cooch Behar	CL, SF	NA WBL
5	Fulpankhari	Cooch Behar	CL, SF	NA WBL
6	Pankhari	Cooch Behar	CL, SF	NA WBL
7	Malshira	Cooch Behar	CL SF	NA WBL
8	Kalonunia	Cooch Behar	CL, SF	NA WBL
9	Khejurchari	24 pgs (South)	CL, SF	NA WBL
10	Valki	Coastal midnapur	CL, SF	NA WBL
11	Gobindobhog	Purulia	CL, SF	NA WBL
12	Kataribhog	Chakdah, Nadia	CL, SF	A WBL
13	Badshahbhog	Chakdah, nadia	CL, SF	A WBL
14	Karnal local-1	India	CL, SF.	TB
15	Mohanbhog	Rangabelia, gosaba	CL SF	A WBL
16	Dee Gee Woo Gen	Irri, Philippines	CD from several crosses	HYV NA
17	Sabita	CRRS, WB, India		HYV INA
18	Peta	IRRI, Philippines	CD from several crosses	HYV NA
19	Kumargore	CRRS, WB, India	CD from several crosses	HYV INA
20	Patnai 23	CRRS, WB, India	CD from several crosses	HYV INA
21	Malabati	Rangabelia, Gosaba	CL, SF	NA WBL
22	Champakushi	Coastal Midnapur	CL, SF	NA WBL
23	Bhasamanik	CRRS, WB, India	CD from several crosses	HYV INA
24	Gayabhog	India	Pure line	IA
25	Matla	CRRS, WB, India	CD from several crosses	HYV INA
26	Chiniatap	Hilli, Cooch Behar	CL, SF	A WBL
27	Meghi	CRRS, WB, India	CD from several crosses	HYV INA
28	Utimerah	IRRI, Philippines	CD from several crosses	HYV NA
29	Pusa Basmati-1	IARI, New Delhi, India	Pusa150/Karnal Local	EB
30	IR 72	IRRI, Philippines	CD from several crosses	HYV NA

A WBL = Aromatic West Bengal landrace, **BCKV**= Bidhan Chandra Krishi Viswavidyalaya, **BI** = Bose Institute, **CD** = complex derivative, **CL** = collection line, **CRRS**= Chinsura Rice Research Station, **EA** = exotic aromatic, **EB** = evolved Basmati, **HYVNA** = high yielding non-aromatic, **IA** = indigenous aromatic, **INA** = indigenous non-aromatic, **IRRI**= International Rice Research Institute, **NA WBL** = Non aromatic West Ben-gal landrace, **S** = selection, **SF** = self-fertilized, **TB**= Traditional Basmati

sure and examined whether they contain any early stage of infestation and have not yet created an emergent hole.

In another set of experiments all the above cultivars were kept in another storage condition facility with 35 ±3^{0}C and 70±5% RH soon after harvest in the same measure. Moisture content and the infection percentage were calculated in the same way. Sterile, healthy grains of cultivars were kept in a Petri plate and inoculated by an average of 10 freshly emerged adults/plate at 30±1^{0}C and 70±5% RH for 20 days. The Petri plate was kept in a wooden box 1ft high, 1.5ft in length and 1ft in breadth, covered by glass on four sides. The roof glass cover can be removed to release or insert the adults if required. The box had a cabinet in the bottom to keep the inoculums

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(infected bulk of susceptible cultivars for periodic release of adults). The Petri plate was kept on a tray which can be removed periodically without disturbing the inoculums. The experiment was set for three replications. After infection, the grains were kept in paper bags for 30 days and the infected grains were counted. Grain moisture content was measured by METREX grain moisture meter.

Table 2. Infestation in a grain condition with low moisture content.

Sl No	CV-Name	Aroma	Silica	Infected	Uninfected	Total	Infestation (%)	Humidity
1	Kajaldekhi	NA	H	6.333333	216.6667	223	**2.657439**	7.9
2	Chotonunia	NA	L	21.66667	242	263.6667	8.086675	8.6
3	Bochi	NA	L	8	145.6667	153.6667	5.792443	7.1
4	Joshoa	NA	L	17.33333	182.3333	199.6667	8.365048	8.7
5	Folpankhari	NA	H	5	236.6667	241.6667	**2.118519**	6.9
6	Pankhari	NA	L	24.33333	250.3333	274.6667	8.860897	8.1
7	Malshira	NA	L	12.66667	156	168.6667	7.528323	8.3
8	Kalonunia	NA	L	6.666667	147.6667	154.3333	4.210972	7.7
9	Khejurchari	NA	L	13.33333	128	141.3333	9.332679	8.1
10	Valki	NA	H	3.666667	145.6667	149.3333	**2.471121**	7.4
11	Gobindobhog	A	H	2.333333	144	146.3333	**1.438008**	7.1
12	Kataribhog	A	L	3.666667	133.3333	137	2.918748	8
13	Badshabhog	A	L	5	122.6667	127.6667	3.700858	7.8
14	Karnal local	A	L	5	77	82	5.787754	8.2
15	Mohanbhog	A	L	43	217.6667	260.6667	19.5058	9.3
16	Dee Gee Woo	NA	L	4	115.3333	119.3333	3.195069	8.3
17	Sabita	NA	L	5.666667	145.6667	151.3333	3.594511	8.7
18	Peta	NA	H	1.333333	113.3333	114.6667	**1.080144**	7.2
19	Kumargore	NA	L	11	148.3333	159.3333	6.903069	8.8
20	Patnai-23	NA	H	0.666667	101.3333	102	**0.490196**	6.3
21	Malabati	NA	HH	0.666667	126.3333	127	**0.512821**	6.7
22	Champakushi	NA	HH	2	132	134	**1.117318**	7.4
23	Bhasamanik	NA	L	4	128.6667	132.6667	2.930666	7.3
24	Gayabhog	A	L	2.666667	120.6667	123.3333	2.078721	7.4
25	Matla	NA	H	2.666667	132.3333	135	**1.868847**	7.2
26	Chiniatap	A	L	36.66667	293.3333	330	11.12065	9.2
27	Meghi	NA	L	2	177	179	**0.724638**	6.7
28	Utrimerah	NA	L	4.333333	143.6667	148	2.850877	7.5
29	Pusa Basmati-	A	L	3.333333	124	127.3333	2.535358	6.9
30	IR 72	NA	H	1.333333	151.6667	153	**0.783167**	7.6

A= Aromatic, NA= Non aromatic, L= Low silica deposition**, H=** High silica deposition on grain hull**,**

HH= Very high silica deposition on grain hull

Examination of Grains for *Sitotroga cerealella* (Olivier) infestation

The intact grains were examined under the microscope for initial surface structure variation of the hull of the tolerant and susceptible cultivars and families. Lemma and palea of the tolerant and susceptible cultivars and families were treated with 25% liquid ammonia (NH_3) for 1 day, H_2O_2 for 4 days and then warmed in dilute HNO_3 till the structure became transparent. The transparent structure was then examined under the microscope for any variation in silica deposition.

Results

The results are shown in two tables.

i) Table 2 shows the infestation tendencies of *Sitotroga cerealella* (Olivier) in the grains which are stored in dry at 35±3^{0}C and 55±5% RH (low moisture storage condition) with the grain moisture content along with the presence/absence of aroma and silica deposition type of the grain hull.

ii) Table 3 shows the infestation tendencies of *Sitotroga cerealella* (Olivier) in more humid at 30±1^{0}C and 70 ±5% RH (high moisture storage condition) with the

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grain moisture content along with the pres-ence/absence of aroma.

As shown in Table III, there is a general increase of the infestation percentage in high moisture storage conditions in all the indigenous rice varieties. But the rate of in-crease differs significantly in the genotypes. When the figures are compared, there is again a difference in the percentage of infestation among the varieties.

with the grain moisture at 9.2. In the high moisture stor-age conditions at 30±1^{0}C and 70±5% RH (grain moisture content is above 10%), the resistance against pests de-creases in many varieties and the average infestation rate increases greatly in some varieties viz., Sabita (3.59% to 41.63%) Karnal Local-1 (5.79% to 45.61%). At low moisture storage conditions the varieties Sabita and Kar-nal Local-1 had relatively less average infestation rate.

Table 3. Infestation under grain conditions of high moisture content.

Sl No	CV-Name	Aroma	Infected	Uninfected	Total	Infestation (%)	Humidity
1	Kajaldekhi	NA	9.333333	195.3333	204.6667	**4.542511**	10.2
2	Chotonunia	NA	60.33333	60.66667	121	49.80323	12.5
3	Bochi	NA	10.33333	87	97.33333	10.46702	12.4
4	Joshoa	NA	17.33333	152	169.3333	10.14718	12.6
5	Folpankhari	NA	32	210	242	13.20207	14
6	Pankhari	NA	26.33333	290.6667	317	8.300029	10.3
7	Malshira	NA	15.33333	179.3333	194.6667	7.84021	10.6
8	Kalonunia	NA	43.66667	172	215.6667	20.22891	12.9
9	Khejurchari	NA	24	132.6667	156.6667	15.28284	13
10	Valki	NA	6.666667	165	171.6667	**3.805368**	10.1
11	Gobindobhog	A	14	106.3333	120.3333	11.47916	10.9
12	Kataribhog	A	9.333333	110	119.3333	7.656619	11
13	Badshabhog	A	8	49.33333	57.33333	13.71624	10.2
14	Karnal local	A	60.66667	73	133.6667	45.60757	13.2
15	Mohanbhog	A	143	217.6667	360.6667	43.68989	13.4
16	Dee gee woo gen	NA	24	128	152	15.76079	12
17	Sabita	NA	48.66667	68.33333	117	41.62978	14
18	Peta	NA	10	137.6667	147.6667	6.762162	10.6
19	Kumargore	NA	14.66667	70	84.66667	17.17759	11
20	Patnai-23	NA	8.666667	123.6667	132.3333	6.499288	9.9
21	Malabati	NA	4	129.6667	133.6667	**2.949053**	10
22	Champakushi	NA	7	172.3333	179.3333	**3.899756**	9.7
23	Bhasamanik	NA	30.33333	100	130.3333	23.90329	11
24	Gayabhog	A	13.33333	137.3333	150.6667	8.805648	11
25	Matla	NA	10.66667	143.3333	154	6.910254	10.3
26	Chiniatap	A	56.66667	268	324.6667	17.41799	12.3
27	Meghi	NA	30.66667	207.6667	238.3333	12.86182	13.6
28	Utrimerah	NA	30.66667	207.6667	238.3333	12.86182	12.9
29	Pusa Basmati-1	A	15.33333	208.6667	224	6.804655	10
30	IR 72	NA	14.66667	265.3333	280	5.213089	11.1

A= Aromatic, **NA**= Non aromatic

Results and Discussion

At low humidity at 35±3^{0}C and 55±5% RH (low mois-ture storage condition) (dried seed, grain humidity below 10%), Mohanbhog shows the highest infestation (19.50%) with the grain moisture at 9.3, whereas Patnai 23 is the least infested variety (0.49%) with the grain moisture at 6.3, as shown in Table 2 and graph 1. The variety Chinatap shows an average infestation of 11.12%

As the storage condition changed from low moisture to high moisture storage condition the average infestation in these two varieties showed a marked increase. Mohan-bhog which had the highest infestation rate in low mois-ture conditions also showed average high infestation rate of 43.69% when the storage conditions were having high moisture content. Other varieties are also highly infested at high moisture storage conditions except for a few *viz.*, Malabati (2.94%), Champakushi (3.89%), Valki (3.80%).

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Champakushi also absorbs low moisture (9.7%) in high humid conditions. This result suggests that the both the storage condition as well as the genotype itself contribute to the infestation rate for the stored grain pest *Sitotroga cerealella* (Olivier). But there are exceptions. Fulpankhari and Sabita contain the highest moisture content, 14% in both. Fulpankhari is only 13.60% infested in contrast to Sabita, which is 41.62% infested. Moisture (grain moisture as well as the storage condition) seems to have an important role in the breakdown of resistance to the pest but there could be other factors.

Both the aromatic and non-aromatic varieties are equally infested by the pest at low humidity, as shown in Table 2. Among the aromatic landraces (A WBL), the low infestation was found in Gobindobhog (1.43%) and Kataribhog (2.91%). High *Sitotroga cerealella* (Olivier) infestation percentages were found in Mohonbhog (19.5%) and Chiniatap (11.12%), both aromatic landraces (A WBL) of West Bengal. Among the non-aromatic land-

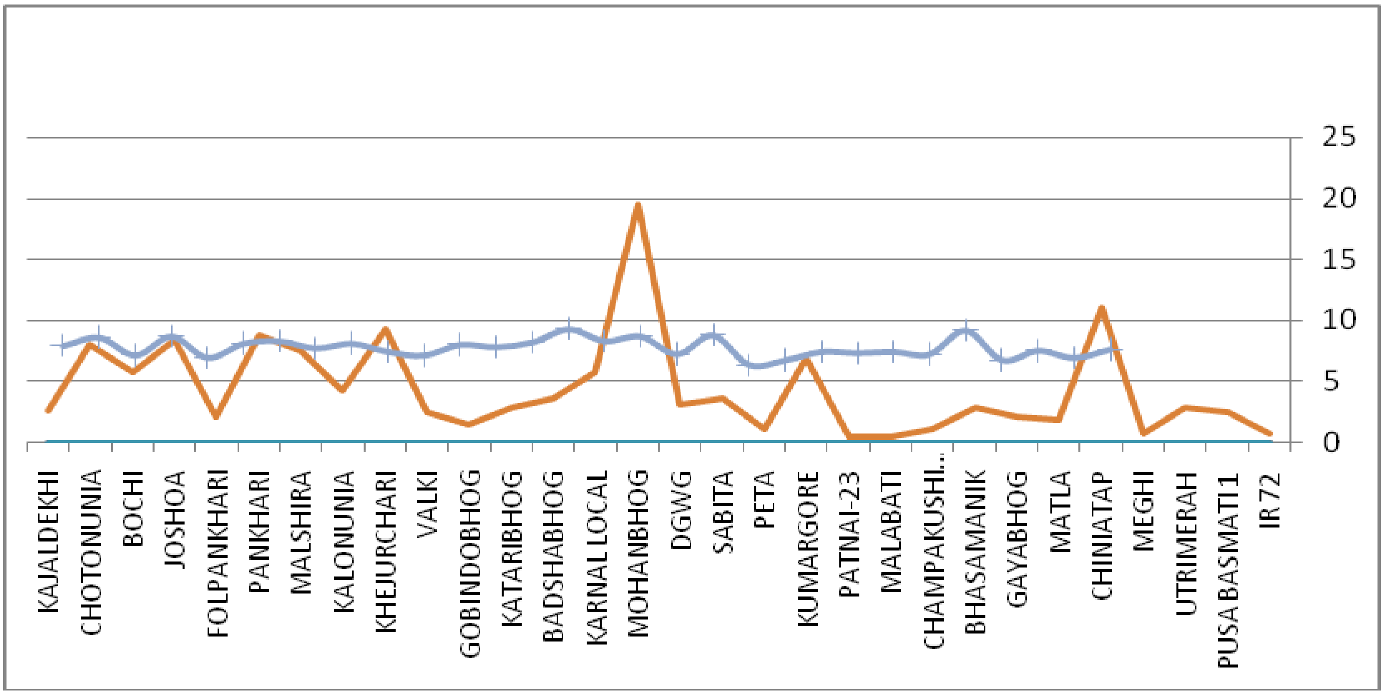

Figure 1. Infestation in a grain condition with low moisture content.

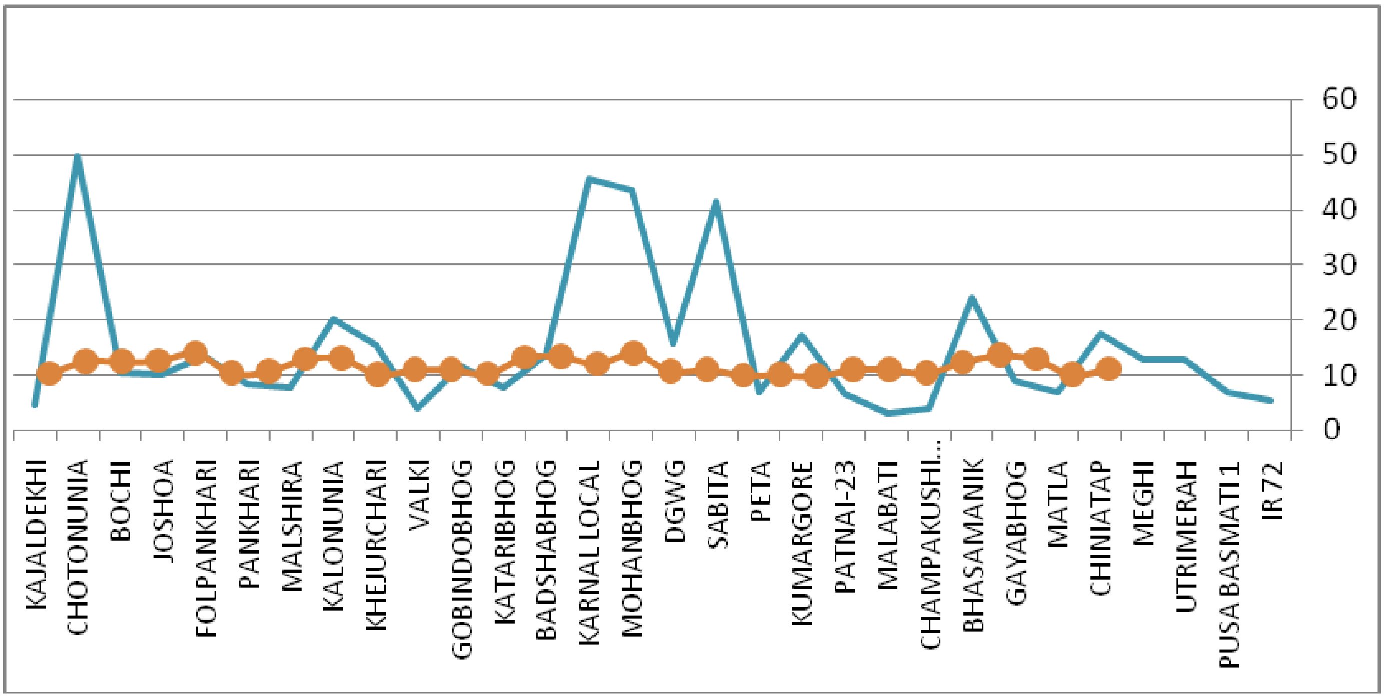

Figure 2. Occurrence of infestation under conditions of excessive grain wetness.

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races of West Bengal (NA WBL) varieties, a high infestation percentage was found in Khejurchari (9.33%), Pankhari (8.86%) and Malshira (7.52%). Aroma is definitely not the deciding factor for infestation. But Table 2 shows that some of the aromatic West Bengal landraces have a very high infestation percentage (≥ 10%).

So the moisture content in the storage condition as well as the rice variety is an important factor in preventing postharvest losses (PHLs) of stored crops. For the improvement of food security while reducing environmental impact and providing economic benefits to the different stakeholders in the food supply chain, the prevention of food loss is a potential strategy (Nicastro et al., 2021). During storage, rice is vulnerable to infestation by a variety of insects, especially *S. cerealella* (Olivier), the angoumois grain moth (Hamed and Nadeem, 2012).

Conclusion

It seems that the moisture content in the storage conditions as well as the grain moisture content is both important factors for tolerance to the stored grain pest, *Sitotroga cerealella* (Olivier) infestation. The inherent tolerance is definitely an important factor but this study reveals that upon changing the storage condition there could be breakdown of resistance to the stored grain pest *Sitotroga cerealella* (Olivier). This investigation also revealed that some rice varieties of West Bengal viz., Champakushi, Malabati and Valki are indigenous rice varieties which are highly tolerant to *Sitotroga cerealella* (Olivier) infestation irrespective of the moisture content in storage conditions. These varieties may be used as donors of the tolerance to *Sitotroga cerealella* (Olivier) infestation in future rice breeding programmes suited for West Bengal.

Conflicts of Interest

No conflicts of interest exist, according to the authors, regarding publishing this study.

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