

Infestation and population build-up of *Sitophilus oryzae* L. in aromatic and non-aromatic stored rice under sub-Himalayan plains of West Bengal

ABSTRACT

The laboratory studies were conducted during 2020-2021 in sub-Himalayan plains of West Bengal. Highest mean grain weight loss due to *S. oryzae* varied from 14.30% - 36.89% in aromatic and non-aromatic cultivars of rice during winter and spring-summer seasons after 9 weeks of storage. The highest mean grain damage % ranged from 36.89% to 41.56%. The grain weight loss and grain infestation % were always higher in the aromatic rice (Uttar Sugandhi) compared to non-aromatic rice (Jaldhepa) and also in the spring-summer season. Carbohydrate and protein content of grains were reduced to the extent 9.08% to 15.28% and 18.62% to 32.58% respectively in aromatic and non-aromatic rice during winter and spring-summer seasons as a result of infestation of *S. oryzae*. During spring-summer season, from 5 pairs of adult weevil, a total of 264 and 237 adults were produced in aromatic and non-aromatic rice cultivars respectively at 9 weeks after their release. The adult population was female biased.

Key words: *Sitophilus oryzae*, aromatic rice, grain loss, carbohydrate and protein content.

INTRODUCTION

Cereal grains are the major sources of proteins and carbohydrates of human diet (Day, 2013). Among cereals, rice is the staple food of Indian population and also half of the world's population (Oko *et al.*, 2012). Apart from protein and carbohydrates, it also contains calcium, iron, zinc, fibre, magnesium, manganese, selenium, B vitamins and other nutrients (Priya *et al.*, 2019). In developing countries, rice supplies food equivalent to 715 kcal/capita/day, 27% dietary energy, 20% dietary protein and 3% of dietary fat (Kennedy and Burlingame, 2003). Rice is stored for an extended period in storages and grain losses in stores are the severe problem in the world (Okram, 2020). Due to substantial post-harvest loss of grains inflicted by stored grain pests, long duration storage of cereals and other products is often not possible (Mainali *et al.*, 2015). During post harvest period grain losses vary from 12-16 million metric tons every year in India (Singh, 2010). Loss of grains due to stored insect pests in storages vary from 9-20% in the developed and developing countries in the world (Phillips *et al.*, 2010; Gad *et al.*, 2022). The damage to stored grains and products is about 20-30% in the tropical region whereas it is 5-10% in the temperate areas of the world (Talukder, 2006; Rajendran and Sriranjini, 2008). In India, about 6.5% of the total grains stored are consumed by pests (Raju, 1984). Among stored grain pests, coleopteran insects are the predominant ones and among storage grain beetles, rice weevil (*Sitophilus oryzae* L.) (Curculionidae, Coleoptera) is one of the most significant and economic insect pests of stored grains and their products (Khan, 2020). It is especially

destructive to numerous cereal grains namely wheat, rice, maize, barley and cereal-based products causing substantial losses, both quantitatively and qualitatively and the insect abounds in warm and tropical area of the world with its ability to thrive well in the cooler region.

In India, though basmati rice is predominantly cultivated in Himachal Pradesh (60%) followed by Uttar Pradesh (17.1%) and Punjab (16.1%), hundreds of indigenous short grain aromatic cultivars and landraces are cultivated in localized areas of different states and almost every state has its own collection of aromatic rice and these perform well in their native areas (Shobha Rani and Krishnaiah, 2001). West Bengal also has a long tradition of growing non-basmati rice in some pockets and the state was rewarded for two aromatic rice cultivars viz. Badshah Bhog and Radhunipagal (localized in Malda and Nadia district respectively) (Priya *et al.*, 2019). In the sub-Himalayan plains of West Bengal e.g. the terai zone, many aromatic rice of local landraces are grown besides the usual non-aromatic types and farmers store the harvested rice for a considerable period for their domestic use as well as for commercial purposes. The warm humid climate of this region is suitable for the infestation of stored grain pests, especially the rice weevil (*S. oryzae*). However, there is lack of information on the extent of loss due to rice weevil to the local landraces of aromatic and non-aromatic types of rice and hence, the study was undertaken.

MATERIALS AND METHODS:

The experiment was conducted in two seasons viz. winter (November, 2020- January, 2021) and summer season (March, 2021- April, 2021).

Maintenance of pure culture of rice weevil, *Sitophilus oryzae* L.

Original pure culture of *Sitophilus oryzae* maintained at the Department of Entomology was used for the study. Ten pairs of adults (5 days old) were released (male and female ratio 1 :1) in 500 g of fresh, disinfested rice grains kept in the plastic containers (2 litre capacity) which were covered with muslin cloth and maintained at room temperature under dark environment for egg laying. Released adults were removed from the containers after 48 hours to avoid the overlapping generation. Five similar sets were made for obtaining good no. of adults. Weevils used for the experiment were those emerged from this fresh culture. Fresh rice grains were supplied in the container at regular intervals for proper development of the adults. For releasing same age -weevils in pairs in the experimental containers, the male and female adults were sexed following the taxonomic keys as per Rees (2004) and Halstead (1963).

For the study, 25 g of fresh, bold and un-infested rice grains of each type viz. local aromatic- **Uttar Sugandhi** (KNS-3-1 developed from Kalonunia, a local aromatic rice landrace) and local non-aromatic rice- **Joldhepa** (a local landrace) were taken in a plastic container (250 g capacity). The rice grains were sterilized in a UV chamber for 30 minutes to kill/ eliminate any inhabiting insect stages or pathogen. Five pairs (male: female-1:1) of newly emerged adults (5 days old) of *Sitophilus oryzae* were released in each of the containers and were covered with a piece of muslin cloth and tied with rubber band for proper aeration and were kept

under black curtain to create a dark environment for normal activity and proper development of the insects. The containers were maintained in the laboratory throughout the course of the study which was extended for nearly two months. The experiment was laid out in a CRD design with five replications. Each container was examined periodically at weekly interval and the record of losses of weight of grains and number of damaged grains were taken. Total no. of adults emerged from each of the containers (i.e. replication) were counted and sexed at 9 weeks after release of the adults.

Various physical parameters of the rice grains viz. length, breadth, moisture content (%), 100 grain weight were estimated before the initiation of the experiment. Similarly biochemical parameters namely initial and final protein (%) and carbohydrate content (%) of the grains were estimated.

Estimation of loss of grain due to infestation of *Sitophilus oryzae*:

Weight loss %

Weight loss of grains was estimated at weekly intervals for consecutive 9 months.

Weight loss of grains was worked out by using the following formula of Adams and Schulton (1978):

$$\text{Weight loss (\%)} = \frac{(\text{UND}) - (\text{DNU})}{\text{U (ND + NU)}} \times 100$$

where,

U - Weight of un-infested grains (g), NU - Number of un-infested grains, D - Weight of infested grains (g) and ND - Number of infested grains

Grain damage%

It was estimated as per the following method:

$$\text{Grain damage (\%)} = \frac{\text{Number of damaged grains}}{\text{Total number of grains}} ;$$

Moisture percentage (%) of grain

The moisture percentage (%) of grains was determined by using High Constant Temperature Oven method. The procedures followed are mentioned below.

$$\text{Grain moisture \%} = \frac{M2-M3}{M2-M1} \times 100$$

where,

M1= Weight of the weighing container with cover in gm.

M2=Weight of the weighing container with cover and rice grains before drying.

M3=Weight of the weighing container with cover and rice grains after drying.

Length and breadth of rice grains

The length and breadth of ten randomly collected grains were measured in mm with the help of a digital Vernier- caliper and the average length and breadth of rice grains were worked out. For length, two terminal tips of the grains were considered while the middle part of the grain was taken into account for the breadth.

100 grain weight (g)

Hundred (100) grains were taken from the seed lot and weight was recorded in grams (g) by an electronic weighing balance (METTLER TOLEDO, ME 104)

Estimation of the biochemical parameters of rice grains:

Total carbohydrate

The total carbohydrate content was estimated by following the Anthrone method (Sadasivam,1996) and using glucose as a standard.

Total protein

The protein content from the grain powder was determined by using the method of Bradford (Bradford,1976).

Results and Discussion:

Grain weight loss (%):

The results presented in Table – 1 and Table-2 revealed that the highest % of weight loss of grains due to *S. oryzae* in aromatic (Uttar Sugandhi) and non-aromatic (Jaldhepa) cultivars was 21.48% and 14.99% during winter and 20.31 % and 13.61% during - Spring-summer seasons, respectively. Thus, grain weight loss % was greater in aromatic rice than non-aromatic type and it was also more in spring – summer season compared to winter months. It was observed that grain weight loss (%) increased significantly at each interval of week. During winter season grain weight loss % was below 5% upto 5 WAS (weeks after storage) (3.07% and 3.05 % in aromatic and non-aromatic rice respectively). However, with successive increase at each interval of weeks, the weight loss figures rose to 14.99 % and 13.61% respectively after 9 WAS i.e. nearly 60 days or two months. In spring-summer season, the weight loss was more than 5% at 5 WAS (8.16 % and 7.70%) in Uttar Sugandhi and Jaldhepa respectively and the grain weight loss was maximum at 9 WAS (21.48% and 20.31% respectively). The results revealed that during spring-summer season there was 6.49% more weight loss in Uttar Sugandhi than that of the winter season infestation.

Grain damage %:

Grain damage due to rice weevil was in greater proportion compared to weight loss of grain (Table 2 and 3). In winter, grain infestation was greater than 5% after 1 WAS in both the cultivars (5.41 % and 5.30% in Uttar Sugandhi and Jaldhepa respectively) and it went on increasing at each interval of weeks. After 5 WAS, the % loss of grain was 10.35 % in aromatic rice while it was 9.55 % in non-aromatic rice. The grain damage % increased to 38.26% and 35.53% in aromatic and non-aromatic rice respectively at 9 WAS.

Similarly, during spring- summer season, grain infestation was higher in both the cultivars in comparison to winter season. Within 1st week of exposure of the grains to the weevils the % of infested grain was 7.46 % and 10.13 % in aromatic and non- aromatic rice cultivars respectively and there was also an increase in infestation at each subsequent week. At 5 WAS the infestation % was 23.00 % and 22.92% respectively and finally at 9 WAS the corresponding figures were 42.29% and 40.84% in aromatic and non- aromatic rice respectively. There was 4.03% higher grain infestation than that of the winter season in case of Uttar Sugandhi. In Jaldhepa, the seed damage was 5.31% more than that of winter season infestation. Thus, grain infestation was always higher in aromatic rice than non-aromatic rice.

The results are in conformity with Khan and Halder (2012) who observed that with increase in storage period of rice there was a gradual increase in infestation % of rice grains. Mondal and Chakraborty (2017) and Okram (2020) also reported that rice grain weight loss (%) and damage (%) increased as the storage duration was prolonged and the loss reached the maximum after 60 days and 90 days respectively.

There are numerous reports on the % weight loss of grains due to *S. oryzae* and the reports vary in the extent of loss/ damage. Bhuiyan *et al.* (1992) observed that after 120 days of storage, *S. oryzae* caused 11-16% weight loss in husked rice. Mondal and Chakraborty (2017) observed 5.1- 21.16% and 12.6- 35.8% weight loss in non-basmati and basmati rice varieties respectively as a result of infestation by rice weevil for a storage time of 60 days. Okram (2020) also found that after 90 days of storage, weight loss % of grains were 21.11% in winter and 29.16% in summer. Mehta *et al.* (2021) obtained 2.66 ± 0.53 % to 14.82 ± 0.38 % and 9.92 ± 4.85 % to 27.16 ± 10.31 % weight loss and grain damage to wheat seed due to rice weevil after 30 days of storage. Thus, our results are in conformity with the above. The difference in the extent of loss/ damage may be due to difference in the variety of the crop, season of study and moisture content of the seeds.

During winter biological activities of the insects are slowed down due to low temperature which reflects in the lower % of grain infestation while the reverse occurs during summer season due to prevalence of higher temperature and humidity. Our results are in agreement with Sinha (1973), Khare and Agarwal (1976), Malgorzata (2011) who reported that temperature and humidity are the two important factors determining the development of population, reproduction and survival of the insect which ultimately reflects in the

infestation and they observed greater % infestation of grains during summer months. The present findings also lend support from Okram (2020) who obtained higher loss of weight of grain % and infested grain % during summer months compared to winter.

Table No 1: Grain weight loss (%) due to *S. oryzae* in aromatic and non-aromatic rice cultivars during winter, 2020 - 21

Cultivar	Grain weight loss (%) at weekly interval												
	Month / week	November				December				January			
		IV	I	II	III	IV	I	II	III	IV			
WAS*		1	2	3	4	5	6	7	8	9			
Uttar Sugandhi		0.40	0.87	1.35	1.96	3.07	5.36	8.17	11.18	14.99			
Joldhepa		0.44	0.71	1.54	2.16	3.05	5.27	7.66	10.83	13.61			
Mean differences		-0.05	0.16	-0.194	-0.196	0.024	0.096	0.504	0.354	1.378			
Mean cultivars		0.42	0.79	1.44	2.06	3.06	5.32	7.92	11.01	14.3			
t- value		-0.236	0.591	-0.745	-0.431	0.057	0.091	0.403	0.180	1.031			
Prob.		0.818	0.570	0.477	0.677	0.955	0.929	0.697	0.861	0.332			

WAS* = weeks after storage Prob.= Probability *Mean of 5 replications

TableNo 2: Grain weight loss (%) due to *S. oryzae* in aromatic and non-aromatic rice cultivars during spring-summer, 2021

Cultivar	Grain weight loss % at weekly interval									
	Month/week	March				April				May
		I	II	III	IV	I	II	III	IV	I
WAS*		1	2	3	4	5	6	7	8	9
Uttar Sugandhi		0.55	2.07	3.14	5.07	8.16	11.25	14.41	17.82	21.48
Joldhepa		0.42	1.83	2.94	4.33	7.70	10.63	13.75	16.91	20.31
Mean differences		0.126	0.24	0.20	0.74	0.46	0.62	0.66	0.91	1.16
Mean cultivars		0.485	1.95	3.04	4.70	7.93	10.94	14.08	17.37	20.89
t- value		0.972	0.480	0.294	1.145	0.457	0.409	0.387	0.427	0.403

Prob.	0.450	0.643	0.775	0.285	0.659	0.692	0.708	0.680	0.696
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WAS*= weeks after storage Prob.= Probability *Mean of 5 replications

TableNo 3: Damaged grains (%) due to *S. oryzae* in aromatic and non-aromatic rice cultivars during winter, 2020- 21

Cultivars	Damaged grains (%) at weekly interval								
	Novembe r	December				January			
	IV	I	II	III	IV	I	II	III	IV
WAS*	1	2	3	4	5	6	7	8	9
Uttar Sugandhi	5.41	8.01	10.35	13.45	17.83	22.18	26.90	31.90	38.26
Joldhepa	5.30	7.84	9.55	12.17	14.80	20.55	25.07	29.72	35.53
Mean differences	0.11	0.17	0.79	1.29	3.04	1.63	1.82	2.18	2.73
Mean cultivars	5.35	7.92	9.95	12.81	16.31	21.37	25.98	30.81	36.89
t- value	0.196	0.193	0.769	0.764	1.406	0.737	0.625	0.632	0.960
Prob.	0.848	0.851	0.463	0.466	0.197	0.481	0.549	0.544	0.364

WAS*= weeks after storage Prob.= Probability *Mean of 5 replications

TableNo 4: Damaged grains (%) due to *S. oryzae* in aromatic and non-aromatic rice cultivars during spring – summer season, 2021

Cultivars	Damaged grains (%) at weekly intervals								
	March				April				May
Month / week	I	II	III	IV	I	II	III	IV	I
WAS*	1	2	3	4	5	6	7	8	9
Uttar Sugandhi	7.46	11.73	15.82	19.11	23.00	27.72	32.08	37.13	42.29
Joldhepa	10.13	10.16	13.74	17.96	22.92	27.41	31.40	36.25	40.84
Mean differences	-2.67	1.57	2.08	1.15	0.08	0.31	0.69	0.88	1.45
Mean Cultivars	8.79	10.64	14.78	18.53	22.96	27.57	31.74	36.69	41.56
t- value	-5.87	1.807	1.082	0.790	0.056	0.142	0.331	0.338	0.455
Prob.	0.573	0.108	0.310	0.452	0.956	0.889	0.748	0.743	0.659

WAS*= weeks after storage Prob.= Probability *Mean of 5 replications

Physical and biochemical parameters of rice grains:

The length and breadth of the Uttar Sugandhi were 6.446 mm and 2.206 mm and 6.344 mm and 2.23 mm respectively in winter and spring-summer respectively while in case of Joldhepa (Table- 5 and 6) the corresponding values were 5.542 mm and 2.106 mm and 5.556 mm and 2.12 mm respectively. During winter and spring –summer season the moisture % of the grains were 11.06% and 11.16% respectively for Uttar Sugandhi while the figures for Joldhepa were 10.64% and 10.76 % respectively. Thus, aromatic rice had greater moisture content than the non-aromatic type. Weight of 100 seeds in case of Uttar Sugandhi was 1.66 gm and 1.69 gm in winter and spring-summer respectively whereas in case of Joldhepa it was 1.53 gm and 1.57 gm respectively (Table 5 and 6).

These results are in agreement with the Arnason *et al.* (1994) reported that weight loss and adult population was more with high moisture %. Okram (2020) also reported that short bold aromatic rice (SBA) had greater loss of weight of grains and number of infested grains due to higher moisture %, breadth, length, 100 grain weight. It is evident from the data furnished in Table 5 and 6 that in aromatic rice, carbohydrate % was more and protein % was less compared to the non-aromatic rice. During both the seasons, there was a reduction in the carbohydrate % and protein % of grains due to infestation of the rice weevil. In winter, the % reduction of carbohydrate and protein in Uttar Sugandhi was 10.722% and was 21.05% respectively whereas it was 9.08% and 18.625% in summer. The % reduction of carbohydrate and protein in Joldhepa was 10.126% and 22.43% during winter whereas it was 15.28% and 32.58% in spring-summer respectively. Thus % loss of protein was more than that of carbohydrate. The reduction % of qualitative parameters of aromatic rice and non- aromatic rice are significant.

Table No 5: Physical and biochemical parameters of aromatic and non-aromatic rice grains during winter, 2020-21

Cultivars	Length (mm)	Width (mm)	Moisture %	Seed weight (100) (g)	Carbohydrate %		Reduction % of carbohydrate	Protein %		Reduction % of protein
					B.I.*	A.I.**		B.I.	A.I.	
Uttar Sugandhi	6.446	2.206	11.06	1.6618	57.825	51.625	10.72	6.792	5.362	21.05
Joldhepa	5.542	2.106	10.64	1.532	47.4	42.6	10.13	9.85	7.6402	22.43
Mean difference	0.90	0.1	0.42	0.12	10.42	9.02	0.59	-3.05	-2.27	1.38
t- value	5.162	0.922	2.238	0.984	9.232	9.248	.869	-15.711	-7.720	.395
Prob.	0.000	0.383	0.055	0.353	0.000	0.000	.410	0.000	0.000	.703

B.I.* = Before infestation

A.I.** = After infestation

Table No. 6: Physical and biochemical parameters of aromatic and non-aromatic rice grains during spring-summer, 2021

Cultivars	Length (mm)	Width (mm)	Moisture %	Seed weight (100) (g)	Carbohydrate %		Reduction % of carbohydrate	Protein %		Reduction % of protein
					B.I.	A.I.		B.I.	A.I.	
Uttar Sugandhi	6.344	2.23	11.166	1.69	55.957	50.875	9.08	6.3242	5.1442	18.63
Joldhepa	5.556	2.12	10.76	1.57	47.425	40.175	15.28	9.4582	6.3762	32.58
Mean diff.	0.788	0.11	0.406	0.12	8.532	10.7	6.20	-3.134	-1.232	13.95
t- value	5.619	2.001	3.108	1.013	5.295	8.261	-5.252	-64.064	-14.873	-17.257
Prob.	0.000	0.080	0.014	0.340	0.000	0.000	.001	0.000	0.000	.000

Mean of 5 replications B.I.* = Before infestation A.I.** = After infestation

Adult weevil population:

Results of the number of adult weevils produced after 60 days of storage (Table 7) show that there was

significant variation in the adult population built-up of rice weevil between the cultivars and also between the seasons. The adult population was more in aromatic rice Uttar Sugandhi during both winter and spring-summer season (188.60, 264.00 respectively) than non-aromatic Joldhepa (142.00, 237.00 respectively). The results also reveal that much higher no. of adults were produced during spring-summer season than winter in both the cultivars. Khan and Haldar (2012) observed that adult rice weevil population

on rice increased gradually with increase in storage period. Bhandari *et al.* (2014) also noticed that adult *S. oryzae* population in different sorghum varieties increased when storage duration was increased. Okram (2020) obtained significantly higher no. of adult weevils of *S. oryzae* in different stored rice varieties during summer (295.47±10.84 to 364.67±11.88) than winter months (155.64±14.06 to 255.70±15.40). She also recorded higher adult weevils in aromatic rice cultivars than non-aromatic types. Thus, our results lend support from the above. It was observed that the female population was higher in both the cultivars and also in both the seasons. The male: female ratio was 1:1.08 and 1:1.12 in case of Uttar Sugandhi in winter and spring-summer season respectively whereas it was 1:1.06 and 1:1.25 in case of Jaldhepa respectively. The results are in accordance with Rajasara and Patel (2019) who observed that adult female population of *S. oryzae* was more than that of male. Bhandari (2015) found that male : female of *S. oryzae* ranged from 1: 1.095 to 1: 1.31 when reared on different sorghum varieties. Similar results were obtained by Khan *et al.* (2014), Bhandari *et al.* (2015), Pradeep and Jagginaver (2015) and Okram (2020). Thus, the results of the present study are in accordance with the above.

Table No 7: Adult population of *S. oryzae* after 9 weeks in aromatic and non-aromatic rice cultivars

Cultivars	Winter season (2020-21)				Spring- summer season (2021)			
	No. of adults			Male: female ratio	No. of adults			Male: female ratio
	Total adults	Male	Female		Total adults	Male	Female	
Uttar Sugandhi	188.60	90.40	98.20	1:1.08	264.00	124.40	139.60	1:1.12
Jaldhepa	142.20	69.00	73.20	1:1.06	237.00	104.40	130.60	1:1.25
Mean of cultivars	165.4	79.7	85.70		250.50	114.40	135.10	
Mean difference	46.40	21.40	25.000		27.00	20.00	9.00	
t- value	5.382	5.077	4.914		5.421	4.724	2.617	
Prob.	0.0006	0.0009	0.0011		0.0006	0.0014	0.0307	

*Mean of 5 replications.

Correlation between grain weight loss%, grain damage%, adult population and different physical and bio-chemical parameters of aromatic and non-aromatic rice

Results of the correlation studies (Table 8) show that % weight loss, % damaged grain and adult population in both aromatic rice and non-aromatic rice had positive association with the length and breadth of rice grains ($r = 0.705$ and $r = 0.096$), weight of 100 grains ($r = 0.147$) and moisture % of seeds ($r = 0.880$); breadth of grain had a very weak positive association ($r = 0.096$). The results further demonstrate that moisture % and the carbohydrate content of the grain had pronounced effect on % of grain weight loss and % grain damage due to rice weevil and adult population. It was observed that loss to grains and adult development was positively correlated with carbohydrate % of the grains ($r = 0.198$ and $r = 0.671$). It was observed that weight loss % of grain had a positive correlation with adult population in Uttar sugandhi and

Joldhepa($r = -0.13$ and $r = 0.17$) while in case of grain damage% and adult population the association was in case uttarsugandhi ($r = 0.07$) and negative in case of joldhepa ($r = -0.18$)

It reveals from the results that between the two rice cultivars, the weevils had a greater preference towards the scented rice, which is reflected from the higher values of % weight loss of grains, % grain damaged as well as adult population developed in scented rice 60days after their release in both the seasons studied in the experiment.

Size and toughness of grains are important determinants to suit the larval development. Tonggjura (2010) studied the relationship between seed size and hardness of seeds and found that smaller seeds were hard, compact and therefore, were more resistant to the insect damage whereas the bigger grains were loose and soft and were more easily attacked by the insects. Russell (1962) noticed that larger varieties of seed of sorghum were most preferred by *S. oryzae* than small size seed. Russell (1968) further observed the weevils preferred larger size of grains. Tewari and Sharma (2002) observed positive association with seed size and rice weevil infestation. Okram (2020) observed that SBA rice (short bold aromatic) experienced the highest % loss of grain (by weight and number) during different seasons as the short bold grains provided greater suitability to the inhabiting larvae. Thus, our results are in line with the above.

The aromatic rice had higher moisture % (11.6% and 11.17% in winter and spring-summer respectively), greater length, breadth, weight of 100 grains and higher % of carbohydrates and lower % of protein in grains compared to those of the non-scented rice (Joldhepa). It is a well-known fact that with the increment of moisture % in seeds there will be increased pests attack as the moisture of the grains influences the oviposition, infestation, reproduction and development of the rice weevils. Aromatic rice Uttara Sugandhi contained higher moisture % (11.06% ,11.17%) than non-aromatic cultivar (Joldhepa) (10.64%, 10.76%) during both the seasons. These results are in agreement with the Arnason *et al.* (1994) and Syed *et al.* (2001) who reported that weight loss and adult population was more with high moisture %. Okram (2020) also reported that short bold aromatic rice (SBA) had greater loss of weight of grains and number of grains due to higher moisture %, breadth, length, 100 grain weight.

The loss of grain was positively correlated with carbohydrate % and negatively correlated with protein %. Carbohydrate is the main part of the endosperm and rice grains contain 70-80% starch, 7 % protein, 1.5% oils and Vitamin A, B and C (Kochhar, 1986). Various workers found that rice grains having more carbohydrate content suffered more *i.e.* higher the amount of carbohydrate higher would be the infestation which was also found in our studies. The findings lend support from Park *et al.* (2003) who observed that the weevil larvae fed on the carbohydrate present in the rice grains causing weight loss and product contamination. Okram (2020) also observed that slender bold aromatic rice (SBA) grains had highest % of carbohydrate and suffered the most in so far as weight loss and damaged grains were concerned. Interestingly, starch and protein content of the grains were negatively associated and as seeds with higher

protein % would serve an indicator of low starch %, will lower down the pest attack (Hucl, 1996) as the weevil prefer carbohydrates. Similar observations have been suggested earlier by Nawrot *et al.* (1985) who found protein content as a parameter responsible for providing resistance to some wheat varieties. Amos *et al.* (1986), Ram and Singh (1996) and Rehaman *et al.* (2000) found a negative correlation between protein content in rice grains and adult weevil infestation suggesting lower infestation and these are in support of the present finding.

Aromatic rice is known to be preferred to insects to non-aromatic types owing to its higher nutritive values and presence of some biochemical constituents which might attract these. However, there are contradictory reports on this aspect. Okram (2020) based on a study with 50 rice cultivars observed that two aromatic landraces viz. Tulaipanji and Mohanbhog (grown in Uttar Dinajpur and Nadia district respectively) suffered the highest grain weight loss of 34.83% and 33.2% respectively due to *S. oryzae* after 90 days of storage which is supportive of the result of the present studies where Uttar Sugandhi suffered higher weight loss % and grain damage%. However, Khan and Haldar (2012) observed that Kalijira, an aromatic rice was least infested by rice weevil. Mondal and Chakraborty (2017) found less infestation in aromatic rice and suggested that the phenolic compounds in rice grains imparted significant negative impact on rice weevil infestation; grain protein content exerted little effect while grain lipid and carbohydrate had moderate effect on grain infestation. Further studies on the presence of various other biochemical compounds may throw some light for the preference of the rice weevil to scented rice.

Table No8: Correlation of grain damage %, weight loss %, adult population with different physical and bio-chemical parameters of rice cultivars

Parameters		Correlation coefficient (r)					
		Grain length	Grain breadth	Moisture %	Seed weight (100)	Carbohydrate %	Protein%
Grain damage %	Uttar Sugandhi	0.705	0.096	0.880*	0.147	0.671	-0.495
	Jaldhepa	0.450	0.518	0.408	0.955*	0.699	-0.717
Weight loss%	Uttar Sugandhi	0.554	0.671	0.537	0.525	0.198	-0.310
	Jaldhepa	0.200	0.668	0.842	0.414	0.704	-0.828
Adult population	Uttar Sugandhi	0.484	0.505	0.338	0.537	0.250	0.483
	Jaldhepa	0.125	0.806	0.767	0.227	0.140	0.069

*Correlation is significant at the 0.05 level (2-tailed).

Conclusion:

Rice weevil is the most common and destructive pest of stored rice in most parts of the world. Higher intensity of grain loss (% by weight and number) and more number of adult weevils emerged after 60 days of storage in scented rice indicate that it supports the physical, biochemical and nutritive requirements of the weevil. Infestation increased with increase in duration of storage period was observed irrespective of the cultivar and season. Magnitude of infestation was higher in spring-summer season than winter months. Sub-Himalayan plains of West Bengal is characterised by warm humid climate, which favours the infestation of stored grain pests. As different aromatic landraces are grown, the degree of infestation due to rice weevil may vary and thus there is a need for further study on this aspect. However, the generated information will help farmers and other stakeholders adopt remediation measures to keep the pest at bay.

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