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Susceptibility of selected cereal crops in storage to rice weevil, *Sitophilus oryzae* (Linnaeus)

AR Bhargude, SK Patil and BV Bhede

Abstract

The present investigation was conducted on susceptibility of selected cereal crops in storage to rice weevil, *Sitophilus oryzae* (Linnaeus) under "Free choice" and "No choice" test during *Kharif* 2019-20. Results revealed that, rice weevil adults oriented towards smaller size seed and highest damage percentage in "free choice" test. In "No choice" test, population of rice weevil increased gradually upto 120 days of released. The maximum population of adult weevils, seed infestation and weight loss was recorded in pearl millet (638.67 adults, 87.00% and 57.26%) and it was less in rice (140.67 adults, 39.33% and 21.79%), respectively. However, the susceptibility of different crops to rice weevil on the basis of population built-up, seed damage and seed weight loss in descending order was pearl millet > wheat > sorghum > maize > barley > rice in no choice test.

Amongst the cereal seeds, there was no any strong relationship recorded with rice weevil population with seed characters and soybean was free from attack of weevil, in free choice test, adult orientation was observed positive correlation with seed damage. In no choice test, population build-up was positive and highly significant correlated with seed infestation (r = 0.949**) and seed weight loss (r = 0.926**). There was positive and highly significant relationship was recorded in between seed infestation and population build-up (r = 0.949**) and seed weight loss (r = 0.992**). It was showed that softer the seed the attack of rice weevil leads to more seed damage and weight loss.

Keywords: Rice weevil, cereals crops, seed infestation, seed weight loss

Introduction

Cereals such as Sorghum, Rice, Wheat, Maize, Pearl millet and Barley are members of the Grass family Poaceae (Also known as Gramineae) and they are especially important to humans because of their role as staple food crops in many areas of the world. Cereals are also used to produce animal feed, oils, flour, starch, sugar, syrup, processed foods, alcoholic beverages, malt, gluten and renewable energy. The introduction of hybrids and high yielding improved varieties during 1960's greatly expanded grain production and a concomitant intensification of insect-pest problems in the world. However, grain yield is still low on the farmer's field due to one or more limitations. Damage due to insect-pests is one of the major factors for low grain yield of sorghum.

Among the various pests associated after post-harvest of the crop, rice weevil (*Sitophilus oryzae* Linnaeus) is one of the noxious storage pest in the tropical and subtropical regions of the world Larvae and adults are internal feeders affecting quality and quantity of grains. Both, adults and grubs damage the grain on which they feed voraciously so the grain is rendered unfit for human consumption as well as for the seed purposes. It has been found that rice weevil infestation alone resulted in sorghum grain damage upto 83.5 percent over a period of six months (Kudachi and Balikai, 2014) [10].

For storing grains successfully insect control is essential. Chemical control measures is accompanied by inherent risks such as toxic residues contaminating the grains, development of resistance by insects, toxicity to consumers and pollution of the environment. An effective chemical used against insect pests in stores must possess the correct blend of high biological activity with low mammalian traits and having the short residual life. Hygienic control measures require good and adequate disinfection, drying and storage practices which are combined with impeccable hygiene that satisfactory results can be achieved. This is achieved in small scale farming system. On the other hand, biological control is an ecofriendly method of control which involves the use of natural enemies and plant products to suppress the insect-pests population. Use of resistance varieties of crops is one such avenue which has been attracting the attention of Entomologists in reducing the pest infestation in field as well as storage. Keeping in this view, the present study was undertaken to study the host preference of rice weevil (*S. oryzae* L.) to different cereal crops.

Material and Methods
The studies on susceptibility of host preference to rice weevil (*Sitophilus oryzae* L.) in storage'' was carried out under laboratory condition during 2019-20 at Department of Agricultural Entomology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani-431402 (Maharashtra), India.

a) Seed
Five hundred grams seed of each crop i.e. sorghum, rice, wheat, maize, pearl millet, barley and soybean was cleaned of straw, chaff, light seeds and other impurities before testing. All the seeds were disinfected by keeping in the oven at 60^0 C for 5 hours before keeping it for oviposition, development, loss in seed weight and percent seed infestation. Initially the moisture content of fresh seed was about 7.26 to 11.14 percent. Moisture content was measured by oven dry method (Chalam *et al*., 1967) [5].

b) Rice weevil culture
To initiate the culture, healthy seeds of sorghum were kept in to 32 cm ×22.5 cm size cylindrical jar and 10 pairs of adult weevils were isolated and released into jar. The mouth of the container was covered with a muslin cloth secured firmly by rubber band. Fresh seeds were provided periodically for the development of weevils. After few days the new adult weevils emergence, the weevils were introduced into healthy sorghum seeds kept in series of cylindrical jars for building up a homogenous population. Density of population per jar was standardized to prevent overcrowding of weevils.

c) Biological study of rice weevil
Hundred healthy and sound seeds from each crop were counted for biology of (*S. oryzae*). These seeds were transferred to plastic containers of 100 g capacity. Five pairs per container were used. The adults of *S. oryzae* from pure culture which were newly emerged were transferred in plastic containers. So that forced choice test was used (Reddy *et al*., 2002) [13]. The containers mouth were covered with the pieces of muslin cloth and fastened with rubber bands and kept in laboratory at room temperature.
The seeds were observed daily up to 80 days for emergence of adults in all cereals seed. The observations were recorded on number of progeny adult's emergence, and period required for incubation, total larval-pupal and development. The growth index was calculated as per the formula.

d) Free choice and No choice test
The experiment on reaction of different crop seeds against rice weevil, *S. oryzae* L. was conducted under "Free choice test and No choice test" in laboratory conditions. The free choice and no choice tests were sensitive in detecting responses for orientation and colonization (Reddy *et al*., 2002) [13]. The details of the experiment are given below.

i) Free choice test
Under 'Free choice test', 100 seeds of each crop was kept in open specimen tubes (5 cm x 3 cm) and arranged horizontally in a circular manner in the trough at equidistance from centre. Approximately 50 pairs of 10 days-old adults of rice weevil females were released in the centre of trough giving free choice to the adults for orientation and then the trough were covered with muslin cloth. The experiment was replicated 3 times. The number of adults oriented in each crop seeds was counted at 24 and 48 hours after their release. The released female rice weevils were placed for one week to lay eggs. After one week, rice weevils were removed. The observations as percent seed damage were recorded at 30, 60, 90 and 120 days after released of rice weevils.

ii) No choice test
Under 'No choice test', 50 g seeds of each crop kept in plastic container having capacity 250 g and 5 pairs of 10 days-old adults were released in each container and the top was kept covered with muslin cloth and tightly fixed with rubber band. After 48 hours after release, all adults were removed. The experiment was replicated 3 times for observations up to 120 days. The seed was counted for knowing the initial weight and number of sound seeds. Each container was examined periodically at monthly interval upto 120 days to note the population build-up (by counting total number of adult weevils at every month), percent damaged seeds and calculated the percent loss in weight.

e) Observations
The physical properties of seeds *viz*., seed coat, colour, size, volume, length and breadth, hardness of seed and hundred seed weight of crop were studied on the basis of characteristic of seed as per the standard methods.
The seed infestation and seed weight loss was calculated by following formula:

$$\text{Seed infestation (\%)} = \frac{\text{Number of damaged seeds}}{\text{Total number of seeds}} \times 100$$

$$\text{Weight loss (\%)} = \frac{\text{Initial wt. of sound seeds - Final wt. damaged seeds}}{\text{Initial wt. of sound seeds}} \times 100$$

f) Statistical analysis
The observations on seed characters, biological parameters of rice weevil and its infestation were recorded as per the standard procedure under different aspect as mentioned above and all these parameters were correlated with each other's by applying simple correlation coefficient method.

Results and Discussion
a) Seed characteristics
The data on seed characters *viz*., seed coat colour, size, volume, length and breadth, hardness of seed and hundred seed weight are presented in Table 1.

b) Influence of rice weevil reared on different seed
Adults of rice weevil were reared on different seed size and colour of crop seeds for their host preference and the data on following biological parameters of rice weevil are presented in Table 1.

Table 1: Influence of biological parameters of rice weevil on seed characters

Sr. No.	Crops	Seed characteristics								Biological parameters				
		Seed Colour	Seed size	Seed volume (10 cc)	Seed length (mm)	Seed breadth (mm)	100 seed weight (g)	Seed hardness (kg/seed)	Seed Moisture (%)	Incubation period (Days)	Total larval-pupal period (Days)	Adult emergence (%)	Development period (Days)	Growth index
1.	Sorghum	Pearl white	Bold	227.33	4.21	4.13	4.09	8.44	10.87	4.67	32.00	18.00	36.67	0.49
2.	Rice	White	Long	391.00	6.87	2.23	1.16	6.16	11.54	6.00	34.00	9.00	40.00	0.23
3.	Wheat	Light yellow	Long	190.67	6.69	2.91	4.64	9.32	11.74	4.33	31.33	21.33	35.67	0.60
4.	Maize	Yellow	Medium	40.67	10.35	7.65	17.15	17.24	11.36	5.33	33.67	16.67	39.00	0.43
5.	Pearl millet	Grayish	Small	421.67	3.17	2.62	1.14	3.75	10.56	4.33	31.67	15.00	36.00	0.42
6.	Barley	Light brown	Long	110.67	8.58	2.98	4.48	8.31	11.24	5.00	32.33	17.00	37.00	0.46
7.	Soybean	Yellow	Bold	43.00	7.31	6.58	12.08	18.43	10.32	0.00	0.00	0.00	0.00	0.00
S.E.(m) ±		-	-	1.61	0.03	0.03	0.06	0.06	0.04	0.25	0.53	0.18	0.48	0.01
C.D. at 5%		-	-	4.94	0.09	0.09	0.19	0.18	0.13	0.77	1.64	0.55	1.28	0.02
C.V. (%)		-	-	1.37	0.80	1.20	1.74	1.01	0.64	10.30	3.33	2.23	2.26	2.85

i) Ovipositional preference

On the basis of adult emergence, female weevil laid less number of eggs into rice as compared to wheat, barley, sorghum, maize and pearl millet. No eggs laid by female weevil in soybean. So that, no any biological observations recorded into soybean. The result showed that variability in the rate of oviposition in different crops was observed due to different degrees of antixenosis for oviposition. These results amply supported to the findings reported by Yevoor (2003) [18] and Adetunji (1988) [2].

ii) Incubation Period

The maximum period of incubation was observed in rice (6 days) followed by maize (5.33 days), barley (5.00 days), sorghum (4.67 days), wheat and pearl millet (4.33 days). The present finding is in agreement with Yevoor (2003) [18] they reported that 5 to 6 days of incubation period on maize grains. Adam Bulo *et al*. (2018) [1] revealed that 3 to 6.33 days of incubation period of rice weevil was reported in seed of different genotypes of sorghum. Rohit Kumar (2018) [15] observed average 5.14 days of incubation period of *S. oryzae* L. on wheat grains.

iii) Larval-pupal period

The minimum larval-pupal period of rice weevil was recorded in wheat (31.33 days) followed by pearl millet (31.67 days), sorghum (32.00 days), barley (32.33 days) and maize (33.67 days). The highest larval-pupal period was recorded in rice (34.00 days). These results are closer agreement with Jadhav (2006) [9] reported that rice weevil of larval and pupal period was 25.8 ± 3.70 and 7.4 ± 0.54 days, respectively on pop sorghum and similar results also reported by Adam Bulo *et al.* (2018) [1].

iv) Adult emergence

The significant less adult emergence was observed in rice (9.00%) followed by pearl millet (15.00%), maize (16.67%), barley (17.00%) and sorghum (18.00%). Whereas, the significantly highest adult emerged was observed in wheat (21.33%). These results are in conformity with Lokhande *et al*. (1986) [12] and Bamaiyi (1998) [3] in sorghum.

v) Developmental period

The least developmental period was observed in wheat (35.67 days) followed by pearl millet (36.00 days), sorghum (36.67 days), barley (37.00 days) and maize (39.00 days). The maximum developmental period was observed in rice (40.00 days). Seeds in which developmental period was longer it means the seeds was less favourable for the growth and development of *S. oryzae*. The fewer eggs laid, longer average larval-pupal period and developmental period of rice weevil indicated clear evidence of less-preference of seeds of different cereal. Results are in conformity with Chandela (2011) [4] who reported that resistant barley varieties extended developmental period of *S. oryzae*.

vi) Growth index

The growth index of *S. oryzae* in wheat proved high i.e., 0.60 followed sorghum (0.49), barley (0.46) and maize (0.43), pearl millet (0.42) and it was less in rice (0.23). The result reveals that rice having maximum developmental period provided minimum growth index, whereas wheat having minimum developmental period provided maximum growth index. The results are in conformity with Gupta *et al.* (1999) [8] who reported that minimum growth index in least preferred varieties in which *S. oryzae* have longer developmental period and maximum growth index in most preferred varieties of maize. Similarly, Adam Bulo *et al*. (2018) [1] reported growth index of *S. oryzae* in sorghum genotypes in ranged from 0.06 to 1.28 and 0.05 to 1.02, respectively.

c) Host preference under free choice condition

The data pertaining to number of female adults oriented towards seed and percent seed damage by rice weevil under free choice test are presented in Table 2.

Table 2: Orientation and seed damage by rice weevil in different seeds under free choice test

Sr. No.	Crop	No. of adult female orientation		Percent damage seed				
		24 hrs	48 hrs	30 DAS	60 DAS	90 DAS	120 DAS	Mean
1.	Sorghum	17.00 (24.35)	19.67 (26.33)	5.77 (13.89)	16.39 (23.87)	27.54 (31.65)	35.44 (36.53)	21.28 (27.47)
2.	Rice	3.33 (10.51)	5.00 (12.92)	1.71 (7.50)	8.24 (16.68)	11.62 (19.92)	17.72 (24.89)	9.82 (18.25)
3.	Wheat	18.00 (25.10)	21.00 (27.27)	6.34 (14.58)	20.02 (26.58)	31.77 (34.31)	39.45 (38.91)	24.40 (29.60)
4.	Maize	15.33 (23.05)	18.33 (25.35)	2.26 (8.65)	9.87 (18.30)	14.61 (22.47)	22.25 (28.14)	12.24 (20.48)
5.	Pearl millet	3.67 (11.04)	6.67 (14.97)	5.94 (14.11)	29.88 (33.14)	48.58 (44.19)	54.44 (47.55)	34.71 (36.10)
6.	Barley	18.00 (25.10)	22.00 (27.97)	5.50 (13.56)	18.60 (25.55)	29.30 (32.77)	36.23 (37.01)	22.41 (28.25)
7.	Soybean	0.33 (3.29)	0.33 (3.29)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
S.E. (m) ±		0.27	0.32	0.57	0.45	0.39	0.32	0.31
C.D. at 5%		0.92	1.10	1.77	1.39	1.22	0.96	0.96
C.V. (%)		5.00	4.86	9.64	3.80	2.59	1.79	2.36

Figures in parentheses are arcsine transformed values DAS- Days after storage

i) Orientation of rice weevil

Out of 100 female adults released, total 75.63 and 93.00 female adults oriented towards different crop seeds at 24 hrs and 48 hrs after released in free choice condition, respectively and rests of them were wondering. At 24 hrs and 48 hrs, maximum adults orientation was observed in barley (18.00 and 22.00), wheat (18.00 and 21.00), sorghum (17.00 and 19.67), maize (15.33 and 18.33) and pearl millet (3.67 and 6.67) and minimum adults oriented towards rice (3.33 and5.00) and the least adults orientation was recorded in soybean (0.33 and 0.33), respectively. There is only one adult weevil orientated towards soybean. None of the cereals showed immunity to the weevil. These results are in line with the findings of Adam Bulo *et al.* (2018) [1] reported that variation in orientation of rice weevil towards different varieties of sorghum, respectively under free choice condition.

ii) Seed damage

The data on percent seed damage was recorded at 30, 60, 90 and 120 days after storage and presented in Table 2.

The significantly less damaged seed was found in rice (1.71%) followed by Maize (2.26%) at 30 days after storage (DAS). Whereas, the maximum damaged seed was recorded in wheat (6.34%) followed by pearl millet (5.94%), sorghum (5.77%), barley (5.50%) and no damage was observed in soybean at 30 DAS. Similar trend was observed at 60, 90 and 120 DAS, the rice crop recorded significantly less damage seed (8.24, 11.62 and 17.72) by *S. oryzae* followed by maize (9.87, 14.61 and 22.25%), sorghum (16.39, 27.54 and 35.44%), barley (18.60, 29.30 and 36.23%), wheat (20.02, 31.77 and 39.45%) and pearl millet (29.88, 48.58 & 54.44%) at 60, 90 and 120 DAS, respectively.

In case of mean seed damage, the ascending order of mean percent seed damage was rice (9.82) < maize (12.24) < sorghum (21.28) < barley (22.41) < wheat (24.40) < pearl millet (34.71). The free choice test proved that soybean seeds was free from attack of pest upto 120 DAS. It was proved that, the cereals has more infestation which has maximum orientation of weevil except pearl millet which has more infestation because number of seeds are small but size, softness and weight of pearl millet was less. These results were proved by Samuel Babarinde *et al.* (2008) [16] who reported that orientation and damage of *S. zeamais* was more in cereals than other crops, cumulative number of adult was significantly higher in small-seeded cereals and cowpea, soybean and pepper did not support reproduction and longevity of *S. zeamais*. Subedi *et al.* (2009) [17] evaluated that under free choice condition rough rice had least preferred by rice weevil than wheat, maize and barley.

d) Reaction of rice weevil adults under no choice condition

The data on population build-up of rice weevil (*S. oryzae* L.), seed infestation and seed weight loss to different crop seeds under no choice condition at 30, 60, 90 and 120 days after storage are presented in Table 3.

Table 3: Population build-up of rice weevil and its infestation in different seeds under no choice test

Sr. No.	Crop	Population build-up (No. basis)					Percent seed infestation (No. basis)					Percent seed weight loss (Wt. basis)				
		30 DAS	60 DAS	90 DAS	120 DAS	Mean	30 DAS	60 DAS	90 DAS	120 DAS	Mean	30 DAS	60 DAS	90 DAS	120 DAS	Mean
1.	Sorghum	40.67	190.33	411.67	596.00	309.67	6.33 (14.57)	20.67 (27.04)	45.33 (42.32)	71.67 (57.84)	36.00 (36.87)	3.90 (11.39)	13.87 (21.87)	26.04 (30.68)	34.91 (36.22)	19.68 (26.34)
2.	Rice	9.00	40.33	86.67	140.67	69.17	3.00 (9.97)	11.33 (16.67)	21.67 (27.74)	39.33 (38.84)	18.83 (25.72)	1.60 (7.27)	5.19 (13.11)	13.13 (21.10)	21.79 (27.82)	10.43 (18.83)
3.	Wheat	42.00	201.67	431.67	619.33	323.75	7.67 (16.08)	24.00 (29.33)	56.00 (48.45)	80.33 (63.67)	42.00 (40.40)	3.97 (11.49)	14.31 (22.22)	30.86 (33.75)	45.82 (42.60)	23.74 (29.16)
4.	Maize	13.33	49.33	109.33	183.00	88.75	5.00 (12.92)	14.67 (22.52)	29.33 (32.79)	47.33 (43.47)	24.08 (29.39)	1.90 (7.92)	9.31 (17.77)	19.12 (25.92)	27.63 (31.70)	14.49 (22.37)
5.	Pearl millet	41.67	203.00	430.33	638.67	328.42	8.33 (16.78)	26.33 (30.87)	60.33 (50.96)	87.00 (68.87)	45.50 (42.42)	4.27 (11.93)	14.52 (22.40)	38.76 (38.50)	57.26 (49.17)	28.70 (32.39)
6.	Barley	30.33	183.67	370.00	555.00	284.75	7.00 (15.34)	21.67 (27.74)	47.00 (43.28)	73.67 (59.13)	37.34 (37.67)	3.27 (10.42)	14.03 (22.00)	28.11 (32.02)	37.11 (37.53)	20.63 (27.01)
7.	Soybean	0.00	0.00	0.00	0.00	0.00	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
S.E. (m) ±		0.97	2.21	5.06	5.20	2.50	0.22	0.42	0.73	0.86	0.26	0.08	0.27	0.51	0.53	0.15
C.D. at 5%		2.99	6.83	15.59	16.04	7.70	0.67	1.28	2.25	2.64	0.78	0.23	0.83	1.56	1.62	0.45
C.V. (%)		6.63	3.09	3.33	2.31	2.16	7.09	4.27	3.43	2.62	1.52	4.85	4.63	3.96	2.86	1.50

DAS- Days after storage

i) Population build-up
At 30 days after released, adult population build-up of rice weevil was significantly less in rice (9) and maximum in wheat (42). Other crops i.e. maize, barley, sorghum and pearl millet recorded build-up the population was 13.33, 30.33, 40.67 and 41.67 adults at 30 DAS. There was no one adult weevil developed in the soybean. Hence no any infestation was recorded in soybean. The significantly lowest population build-up was recorded in rice (40.33, 86.67 and 140.67) crop followed by maize (49.33, 109.33 and 183.00), barley (183.67, 370.00 and 555.00), sorghum (190.33, 411.67 and 596.00), wheat (201.67, 431.67 and 619.33) and pearl millet (203.00, 430.33 and 638.67) at 60, 90 and 120 DAS, respectively.
Similar trend was noticed as mean of population build-up. However, the mean highest and lowest number of adult weevils was recorded in pearl millet (328.42) and rice (69.17), respectively. Rest of the crops i.e. maize, barley, sorghum and wheat recorded mean seed damage was 88.75, 284.75, 309.67, 323.75 cent, respectively. It is evident from these results that among different cereals seed, the weevil population increased by approximately 10 times of initial number. These result proved that finding of Yevoor (2003) [18] recorded the population build-up of rice weevil in barley (466) followed by wheat (456), sorghum (431), bajara (411), ragi (400) and foxtail millet (389) in these cereal grains after 90 days and he also reported that there was average number of weevils were developed in all cereal grains and severely attack on it.

ii) Seed infestation
Significantly less infestation was found in the rice (3.00, 11.33, 21.67 and 39.33%). The next promising crop was maize which was recorded 5.00, 14.67, 29.33 and 47.33 percent seed infestation followed by sorghum (6.33, 20.67, 45.33 and 71.67%), barley (7.00, 21.67, 47.00 and 73.67%), wheat (7.67, 24.00, 56.00 and 80.33%) and pearl millet (8.33, 26.33, 60.33 and 87.00%) at 30, 60, 90 and 120 DAS, respectively.
The overall mean infestation shows that the significantly minimum infestation was recorded into the rice (18.83%) and next ascending order of infestation was maize (24.08%) < sorghum (36.00%) < barley (37.34%) < wheat (42.00%) < pearl millet (45.50%). These finding are in accordance with the results reported by Subedi *et al.* (2009) [17] reported that wheat was the most preferred host than barley, maize and rough rice under no choice conditions.

iii) Seed weight loss
At 30 days after storage, the significantly minimum seed weight loss recorded in rice (1.60%) and which was at par with maize (1.90%). The significantly highest weight loss was recorded in pearl millet (4.27%) followed by wheat (3.97%), sorghum (3.90%) and barley (3.27%) and in soybean there was no any damage observed. Whereas, at 60, 90 and 120 DAS, the significantly highest weight loss was recorded in pearl millet (14.52, 38.76 and 57.26%) and significantly less seed infestation in rice (5.19, 13.13 and 21.79%) followed by maize (9.31, 19.12 and 27.63%), sorghum (13.87, 26.04 and 34.91%), barley (14.03, 28.11 and 37.11%) and wheat (14.31, 30.86 and 45.82%), respectively.
Similar trend was observed at the mean of seed weight loss over 120 days of storage. However, the significantly minimum loss percentage was observed in rice (10.43%) followed by maize (14.49%). The significantly highest seed weight loss was recorded in pearl millet (28.70%) followed by wheat (23.74%), barley (20.63%) and sorghum (19.68%). Overall, the extent of seed damage and weight loss increased significantly among cereals with passage of storage time during four month. These finding are supported with the results reported by Ladang *et al.* (2008) [11] revealed that the losses of grains due to rice weevils estimated to an average of 25 to 40 percent after 100 days of storage. They indicated that there is an association in adult emergence from seeds of sorghum with seed infestation and seed weight loss under no choice test and also the less seed weight loss in resistant genotypes might be due to low seed damage by *S. oryzae*. Also indicated seed weight loss was to be the best indicator of economic loss from damage by weevils. Kudachi and Balikai, (2014) [10] reported that rice weevil infestation alone resulted in sorghum grain damage up to 83.5 percent over a period of six months. Yevoor (2003) [18] reported that the grain infestation was increased with increase of pest population and causes more weight loss in cereals. The weight loss of different cereals is due to physio-chemical properties of cereals seed.

e) Correlation coefficient
i) Correlation coefficient 'r' between seed characters with biological parameters of rice weevil
The results presented in Table 4 indicated that there was no any significantly relationship was observed between seed characters and biological parameters of rice weevil. However, showed the morphological characters *viz.* seed volume and seed moisture showed positively and negatively correlated with the biological parameters of the rice weevil and other characters of seeds were negatively non-significant correlated. These findings are supported with Chauhan *et al.* (2005) [5] they reported that weight and volume of 100 seeds of wheat varieties influence positive indication on biological activities of *S. oryzae*. Adam Bulo *et al.* (2018) [1] showed that seed hardness of seed was negatively correlated with biological parameters of rice weevil. Adetunji (1988) [2] found that developmental period were significantly longer in resistant than in susceptible varieties. Regupathy and Rathanswamy (1970) [14] who observed no association of seed colour, seed volume and hardness of seed.

ii) Correlation coefficient 'r' between seed characters with rice weevil under free choice test
The results presented in Table 4, showed all the morphological characters *viz.* seed volume, seed breadth and seed hardness have non-significant and negatively correlated with rice weevil orientation. Also seed length, 100 seed weight and seed moisture was positively, non-significantly correlated with orientation of *S. oryzae* adults towards the seeds for host preference. The seed damage was negatively significant correlated with seed hardness (r= - 0.755*) and negatively non-significant correlated seed length, seed breadth and hundred seed weight of seed characteristic with rice weevils. Whereas, positively non-significantly correlated with seed volume, seed moisture and adults oriented towards seeds. There was positive correlation of adult orientation with percent seed damage (r= 0.445). The results are similar with the results of Chunni Ram and Singh (1996) [7] reported that susceptibility to rice weevil was found to be correlated with seed size and negatively with seed hardness in wheat. Also reported similar results by Yevoor (2003) [18] in wheat and Adam Bulo *et al.* (2018) [1] in sorghum.

Table 4: Correlation coefficient 'r' between seed characters with biological parameters of rice weevil and its seed infestation

Particulars	Correlation coefficient 'r' of								
	Seed volume	Seed length	Seed breadth	100 seed weight	Seed hardness	Moisture content	No. of adults oriented	Population build-up	Seed damage
Seed characters x Biological parameters of rice weevil									
Incubation period	0.434	0.060	-0.441	-0.350	-0.573	0.712	-	-	-
Total larval-pupal period	0.449	-0.056	-0.475	-0.389	-0.629	0.666	-	-	-
Adult emergence	0.122	-0.072	-0.321	-0.225	-0.429	0.581	-	-	-
Development period	0.451	-0.043	-0.470	-0.384	-0.623	0.675	-	-	-
Growth index	0.139	-0.117	-0.351	-0.257	-0.450	0.557	-	-	-
Seed characters x Adult orientation x Seed damage (Under Free choice test)									
No. of adults oriented	-0.299	0.250	-0.067	0.043	-0.099	0.570	1.000	-	-
Seed damage	0.523	-0.557	-0.599	-0.580	-0.755*	0.107	0.445	-	-
Seed characters x Seed damage x Seed weight loss (Under No choice test)									
Population built-up	0.355	-0.538	-0.595	-0.581	-0.680	0.148	-	1.000	0.949**
Seed damage	0.429	-0.416	-0.587	-0.534	-0.716	0.316	-	0.949**	1.000
Seed weight loss	0.464	-0.444	-0.562	-0.515	-0.713	0.255	-	0.926**	0.992**

***Significant at 5% = 0.754, ** Significant at 1% = 0.874

iii) Correlation coefficient 'r' between seed characters with adults population of rice weevil under no choice test

The results presented in Table 4, showed all the morphological characters *viz*. seed length, seed breadth, 100 seed weight and seed hardness was negatively and non-significant correlated with population build up, seed infestation and seed weight loss. Whereas, population build-up of rice weevils was highly significant and positively correlated with seed infestation (r= 0.949**) and seed weight loss (r= 0.926**) that means seed infestation and weight loss increases with population and also seed infestation has highly significant and positively correlated with seed weight loss (r= 0.992**). Seed infestation and seed weight loss was found negatively and non-significant correlated with seed length, seed breadth, 100 seed weight and seed hardness and it was non-significantly positive correlated with seed volume and seed moisture. These results are in conformity with Chunni Ram and Singh (1996) [7] revealed that significant and negative correlations between seed hardness, grain infestation and percent loss in seed weight. Adam Bulo *et al.* (2018) [1] reported that the number of damaged seeds was positively correlated with insect population.

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