Indian Journal of Entomology Online published Ref. No. e24020 DoI. No.: 10.55446/IJE.2024.2020

FOOD BAIT ATTRACTANTS FOR MONITORING PESTS IN STORED PADDY

M Sathiyaseelan[1]*, J Jayaraj[2], M Shanthi[3] and K Sujatha[4]

[1]Department of Agricultural Engineering, Sethu Institute of Technology, Virudhunagar, 626115, Tamil Nadu, India
[2]Department of Agricultural Entomology, [4]Department of Seed Science and Technology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai 625104, Tamil Nadu, India
[3]Centre for Plant Protection Studies, Tamil Nadu Agricultural University, Coimbatore 641003, Tamil Nadu, India
*Email: sathiyaseelanm1998@gmail.com (corresponding author): ORCID ID 0000-0001-9587-3071

ABSTRACT

Food baits are one of the ways for monitoring and mass trapping of stored product insects. Based on this principle, wheat, sorghum, pearl millet and rice flours, cracked corn, crushed groundnut, rice bran + rice flour were evaluated as attractive materials. Observations were recorded on 25 days after placement of bait traps. Behavioural response of insects to the baits tested showed that wheat flour, cracked sorghum and pearl millet flour were found to be the most attractive baits. Wheat flour attracted 99.47% of *Sitotroga cerealella* and 63.64% of *Sitophilus oryzae*. Cracked sorghum registered an attraction of 79.62% of *Rhyzopertha dominica* and 61.97% of *Tribolium* spp. and the pearl millet flour attracted 81.91% of *Oryzaephilus surinamensis*. The effective baits were also test verified through four-arm olfactometer and found the highest orientation in the arm containing wheat flour by attracting 34% of *R. dominica* in 15 minutes after release (MAR), 40% of *Tribolium* spp. at 20 MAR and 32% of *S. oryzae* at 15 MAR. Therefore, the effective bait of wheat flour may be exploited for monitoring and trapping of insects in paddy storage godowns.

Key words: Bait traps, rice godown, stored product insects, wheat flour, food bait attractants, lesser grain borer, rice weevil, saw-toothed grain beetle, red flour beetle,

Angoumois grain moth Rice is one of the most important food crops for more than half of the world's population. Large number of people affected by food shortage/ crisis due to losses in storage. In storage godown, number of biotic and abiotic agents like insects, birds, mites, fungi, rodents and moisture are causing damage to rice (Prakash and Kauraw, 1982). Storage insects cause considerable losses every year. Although it is very difficult to detect the activity of insects visually in storage godown, detection of insect population using bait trap with pheromones or food sources or combination of both pheromone and food attractants may be of help in stored product insect management. The food bait material used for detecting stored product insects may be a liquid or solid. The ability of food baits to attract insects is dependent on the presence of attractants (Subramanyam et al., 1992). Olfactory cues play an important role as attractants, and diversity of substances are as kairomone for stored product pests (Rizana and Phillips, 2007). The granary weevil, *Sitophilus granarius* is the most widely studied storage insect species with regard to its response to kairomone, with its reaction to crushed seed or whole seed (Reidorf and Steidle, 2002). The present study aims at to know the response of insects to different host odours in paddy storage godowns. The main objective of the study was to identify an easily available, cheap and effectively attracting bait source for major pests in stored paddy.

MATERIALS AND METHODS

Bait traps were designed using rust proof hallow cylinder (23 cm long and 5 cm dia) with evenly spaced 4 mm hole which can hold 50g bait material. One end of the trap was closed by a removable cap and another end was tied with polythene cover. Uninfected whole sorghum, maize, groundnut was cracked and wheat, rice, bajra were ground in a wiley mill. The treatment details are crushed groundnut, wheat flour, cracked corn, sorghum flour, rice flour, pearl millet flour, rice bran, rice bran + rice flour, cracked sorghum and control (without bait material). The bait traps pre - filled with bait materials and inserted into the interspace between the bags arranged in the stack of the godown (14.5 x

6.5 x 3.5 m) and oriented in such a way the insects would enter through the 4mm hole and be dropped into the bottom part of the polyethene receptacle. The trap catches of *Sitotroga cerealella, Rhyzopertha dominica, Tribolium* spp., and *Sitophilus oryzae*. The number of insects caught in control (without bait material) was compared with the number of insects caught in other treatments. The formula used to calculate the attraction index, as given by Smith et al. (1993). In plastic jar, adults of *R. dominica*, *S. oryzae*, and *Tribolium* spp., were mass produced. The insects were fed with wheat flour and wheat grains as a diet. Twenty to thirty pairs of each insect species were placed in plastic jars containing 250 g of grains. A piece of kada cloth was secured to the jars with rubber bands. The cultures were kept in a controlled environment with a 12:12 hr light: dark photoperiod, temperatures between 26 and 28°C and relative humidity levels between 60 and 65%. All of the experiments were carried out under the identical circumstances where the cultures were kept.

Three different odour sources such as wheat flour, sorghum flour and pearl millet flour were selected for olfactometer bioassay. To study the chemoreception and attraction, the experiment was conducted by using an olfactometer apparatus. It consisted of square-shaped box with four horizontal side tubes. A plastic box (25x 25x 11.5 cm) was supported at the bottom by four supports with a removable top of the centre for the insertion of test insects. The protruded four arms from the plastic box were linked to the container which contained the odour samples. The air pumping system was linked to this volatile container to attract the test insects. To produce the vacuum, a suction pump was connected to the glass container independently. The corners of the plastic box were blocked to prevent insects from moving and resting in the corners, as well as to cause the insects to migrate towards their favourite volatiles. The olfactometer was first cleaned with 70% ethanol to minimize odour residue. Purified air was pumped into the four arms via teflon tubes from an air delivery system for 45 min before and after each experiment, a vacuum was generated within the olfactometer to keep the volatiles from mixing.

Test insects viz., *R. dominica, Tribolium* spp. and *S. oryzae* were starved for 24 hr in petri plates before the commencement of olfactory bioassay. Fifty unsexed adults were released in the centre of the olfactometer (7 mm hole) and it was covered with cloth to minimise the phototactic response of insects. At 5, 10, 15, 20, 25 min after release (MAR), the location of the insects was observed (Vijay et al., 2020). Each treatment was replicated 5 times. The response of *R. dominica, Tribolium* spp. and *S. cerealella* was assessed on wheat flour, sorghum flour and pearl millet flour. On each arm, the numbers of settled and unsettled insects were observed. The attraction index and the difference in the behavioural response/orientation of the beetles were analysed using completely randomized design (CRD) by one-way ANOVA subjecting to the data to arcsine transformation and were separated by using DMRT (duncan's multiple range test) with SPSS 22.0 software and differences were regarded as significant at $p < 0.05$.

RESULTS AND DISCUSSION

The observations indicated that attraction of *S. cerealella, R. dominica, Tribolium* spp., *S. oryzae, O. surinamensis* adults varied with food attractants. Among the food bait attractants tested, wheat flour was found to be the most attractive material effecting 18.01% attraction of *S. cerealella* followed by sorghum flour (13.93%), pearl millet flour (13.28%) and the least attraction with rice bran (4.28%) by 5 days after placement (DAP). In the study of comparative efficacy of different food attraction to various storage insect pests it was found that the wheat flour and pearl millet flour were more attractive to *S. cerealella*. The results are in line with the findings of (Ahmad et al., 2013) in which *R. dominica* had been attracted more towards wheat flour. Earlier other studies also indicated that larger grain borer, *Protephanus truncates* and *R. dominica* had a positive attraction towards cereal host odour (Bashir et al., 2001; Edde and Phillips 2006; Ukeh and Umoetok, 2007) and examined that the response of *R. dominica* to host and non host plant volatile, both male and female *R. dominica* significantly preferred winter wheat seeds and maize. Crushed groundnut attracted a higher number of *R. dominica* than rice flour or wheat grains (Mohan, 1993).

The corresponding attraction of *S. cerealella* at 10 DAP was 13.67, 11.72, 10.99 and 3.9% with wheat flour, sorghum flour, pearl millet flour and rice bran, respectively. The total attraction of 99.47% was observed in wheat flour followed by sorghum flour 54.87%, pearl millet flour 53.43%, cracked sorghum 39.46%, cracked corn 34.01% and the least attraction with crushed groundnut 26.62% (Table 1). According to Ahmad et al. (2013) *T. castaneum* is more attracted to cotton seed than wheat, whereas *R. dominica* was attracted to wheat. In our study a greater number of *Tribolium* spp were strongly attracted to cracked

Table 1. Comparative response of stored pests for food bait attractants

Attractants	Relative attraction index (%)					Total attraction (%)
	5 DAP *	10 DAP	15 DAP	20 DAP	25 DAP	
S. cerealella						
Wheat flour	18.01 (25.11)^{a}	13.67 (21.70)^{a}	23.34 (28.89)^{a}	23.44 (28.96)^{a}	21.01 (27.28)^{a}	99.47
Cracked corn	6.46 (14.72)^{d}	6.13 (14.33)^{e}	6.51 (14.78)^{e}	7.82 (16.24)^{c}	7.09 (15.44)^{f}	34.01
Sorghum flour	13.93 (21.91)^{b}	11.72 (20.02)^{b}	11.70 (20.00)^{b}	9.55 (18.00)^{b}	7.97 (16.40)^{d}	54.87
Rice flour	5.28 (13.29)^{e}	5.86 (14.01)^{ef}	5.36 (13.38)^{g}	5.75 (13.87)^{e}	7.44 (15.83)^{e}	29.69
Pearl millet flour	13.28 (21.38)^{b}	10.99 (19.36)^{c}	10.08 (18.52)^{c}	9.81 (18.25)^{b}	9.27 (17.73)^{b}	53.43
Rice bran	4.28 (11.94)^{f}	3.94 (11.44)^{h}	3.81 (11.25)^{i}	7.72 (16.13)^{c}	8.35 (16.80)^{c}	28.10
Rice bran + rice flour	5.64 (13.74)^{e}	4.59 (12.37)^{gh}	4.26 (11.92)^{h}	4.80 (12.65)^{f}	7.50 (15.90)^{e}	26.79
Cracked sorghum	9.38 (17.83)^{c}	8.60 (17.05)^{d}	7.66 (16.07)^{d}	6.70 (15.01)^{d}	7.12 (15.48)^{f}	39.46
Control	0.00 (0.52)^{g}	0.00 (0.52)^{i}	0.00 (0.52)^{j}	0.00 (0.52)^{g}	0.00 (0.52)^{h}	0.00
R. dominica						
Crushed groundnut	4.32 (12.00)^{de}	6.85 (15.17)^{d}	8.16 (16.60)^{de}	8.46 (16.91)^{d}	9.31 (17.76)^{b}	37.09
Wheat flour	10.55 (18.95)^{b}	11.69 (20.00)^{b}	11.63 (19.94)^{b}	9.62 (18.07)^{c}	8.48 (16.93)^{c}	51.98
Cracked corn	7.84 (16.26)^{c}	9.41 (17.86)^{c}	7.71 (16.12)^{e}	7.53 (15.93)^{ef}	7.42 (15.81)^{e}	39.91
Sorghum flour	5.27 (13.28)^{d}	6.12 (14.32)^{d}	8.28 (16.72)^{de}	7.57 (15.97)^{e}	7.75 (16.16)^{d}	34.99
Rice flour	3.52 (10.81)^{ef}	5.11 (13.07)^{e}	4.14 (11.74)^{f}	4.23 (11.87)^{h}	4.04 (11.60)^{g}	21.04
Pearl millet flour	6.71 (15.01)^{c}	6.48 (14.75)^{d}	10.12 (18.55)^{c}	9.95 (18.39)^{b}	9.34 (17.80)^{b}	42.60
Rice bran	2.87 (9.76)^{f}	2.92 (9.84)^{f}	4.25 (11.89)^{f}	5.52 (13.58)^{g}	6.92 (15.25)^{f}	22.48
Rice bran + rice flour	9.92 (18.36)^{b}	9.32 (17.77)^{c}	8.67 (17.12)^{d}	7.21 (15.58)^{f}	6.66 (14.95)^{f}	41.77
Cracked sorghum	25.09 (30.06)^{a}	18.36 (25.37)^{a}	13.53 (21.58)^{a}	11.72 (20.02)^{a}	10.93 (19.31)^{a}	79.62
Control	0.00 (0.52)^{g}	0.00 (0.52)^{g}	0.00 (0.52)^{g}	0.00 (0.52)^{i}	0.00 (0.52)^{h}	0.00
Crushed groundnut	4.32 (12.00)^{de}	6.85 (15.17)^{d}	8.16 (16.60)^{de}	8.46 (16.91)^{d}	9.31 (17.76)^{b}	37.09
Tribolium spp.						
Crushed groundnut	8.49 (16.94)^{c}	9.52 (17.97)^{b}	10.57 (18.97)^{c}	9.11 (17.57)^{d}	8.07 (16.51)^{d}	45.77
Wheat flour	10.32 (18.73)^{b}	8.40 (16.85)^{c}	8.60 (17.06)^{d}	10.44 (18.85)^{c}	8.93 (17.39)^{c}	46.69
Cracked corn	6.39 (14.64)^{d}	6.61 (14.89)^{d}	5.03 (12.96)^{f}	4.32 (11.99)^{g}	3.35 (10.54)^{h}	25.69
Sorghum flour	11.94 (20.21)^{a}	10.08 (18.51)^{b}	12.90 (21.05)^{b}	11.72 (20.02)^{b}	11.94 (20.22)^{b}	58.58
Rice flour	2.96 (9.91)^{g}	3.36 (10.57)^{e}	4.23 (11.87)^{g}	3.66 (11.02)^{h}	5.21 (13.19)^{f}	19.42
Pearl millet flour	4.35 (12.04)^{fg}	4.15 (11.75)^{e}	4.52 (12.27)^{fg}	4.32 (11.99)^{g}	5.36 (13.38)^{f}	22.69
Rice bran	4.58 (12.36)^{efg}	3.25 (10.38)^{e}	3.94 (11.44)^{g}	6.98 (15.32)^{e}	7.66 (16.07)^{e}	26.41
Rice bran + rice flour	5.72 (13.84)^{def}	8.18 (16.61)^{c}	6.49 (14.76)^{e}	5.36 (13.39)^{f}	4.39 (12.09)^{g}	30.13
Cracked sorghum	6.19 (14.41)^{de}	15.12 (22.89)^{a}	13.85 (21.85)^{a}	13.72 (21.74)^{a}	13.10 (21.22)^{a}	61.97
Control	0.00 (0.52)^{h}	0.00 (0.52)^{f}	0.00 (0.52)^{h}	0.00 (0.52)^{i}	0.00 (0.52)^{i}	0.00
S. oryzae						
Crushed groundnut	5.62 (13.71)^{b}	4.74 (12.57)^{cd}	3.54 (10.84)^{de}	3.78 (11.22)^{ef}	2.62 (9.31)^{cd}	18.24
Wheat flour	5.62 (13.71)^{b}	16.94 (24.30)^{a}	14.00 (21.97)^{a}	13.33 (21.41)^{a}	13.38 (21.46)^{a}	63.64
Cracked corn	5.62 (13.71)^{b}	5.66 (13.77)^{cd}	4.16 (11.76)^{cd}	6.29 (14.53)^{cde}	5.55 (13.63)^{bc}	27.49
Sorghum flour	4.23 (11.86)^{b}	13.24 (21.33)^{ab}	14.59 (22.46)^{a}	13.53 (21.58)^{a}	11.75 (20.05)^{a}	57.76
Rice flour	5.62 (13.71)^{bc}	5.72 (13.84)^{cd}	5.56 (13.64)^{cd}	5.07 (13.01)^{def}	7.17 (15.54)^{b}	29.30
Pearl millet flour	7.07 (15.41)^{b}	5.61 (13.70)^{cd}	3.46 (10.72)^{de}	9.70 (18.14)^{b}	8.16 (16.60)^{b}	34.30
Rice bran	5.62 (13.71)^{b}	5.61 (13.70)^{cd}	7.03 (15.37)^{bc}	8.08 (16.51)^{bc}	7.18 (15.54)^{b}	33.76
Rice bran + rice flour	7.07 (15.41)^{b}	4.68 (12.50)^{cd}	3.54 (10.84)^{de}	2.50 (9.10)^{fg}	3.25 (10.38)^{cd}	20.31
Cracked sorghum	11.29 (19.64)^{a}	9.48 (17.93)^{bc}	9.03 (17.49)^{b}	7.57 (15.97)^{bcd}	8.16 (16.60)^{b}	45.78
Control	0.00 (0.52)^{c}	0.00 (0.52)^{d}	0.00 (0.52)^{e}	0.00 (0.52)^{g}	0.00 (0.52)^{d}	0.00

(Table contd.)

(contd. Table 1)

O. surinamensis						
Crushed groundnut	4.06 (11.62)^{cde}	4.10 (11.68)^{cde}	7.05 (15.39)^{c}	3.93 (11.43)^{de}	2.99 (9.95)^{cd}	22.12
Wheat flour	7.94 (16.37)^{bc}	6.42 (14.68)^{bc}	8.56 (17.01)^{c}	7.10 (15.45)^{bc}	5.97 (14.14)^{b}	35.99
Cracked corn	3.81 (11.25)^{cde}	3.39 (10.61)^{def}	2.79 (9.61)^{d}	3.56 (10.87)^{e}	2.10 (8.32)^{de}	15.63
Sorghum flour	9.36 (17.82)^{b}	7.97 (16.40)^{b}	12.21 (20.45)^{b}	8.20 (16.64)^{b}	6.86 (15.19)^{b}	44.61
Rice flour	2.59 (9.27)^{de}	1.21 (6.32)^{ef}	3.68 (11.05)^{d}	3.36 (10.57)^{e}	1.79 (7.70)^{de}	12.64
Pearl millet flour	22.13 (28.06)^{a}	16.90 (24.27)^{a}	18.92 (25.79)^{a}	12.31 (20.54)^{a}	11.65 (19.95)^{a}	81.91
Rice bran	6.49 (14.75)^{bcd}	3.95 (11.46)^{cde}	6.70 (15.01)^{c}	5.03 (12.96)^{d}	7.16 (15.52)^{b}	29.33
Rice bran + rice flour	4.22 (11.86)^{cde}	5.18 (13.15)^{bcd}	7.99 (16.41)^{c}	3.56 (10.87)^{e}	3.45 (10.70)^{c}	24.39
Cracked sorghum	7.19 (15.56)^{bcd}	6.87 (15.20)^{bc}	7.95 (16.38)^{c}	6.35 (14.60)^{c}	5.98 (14.15)^{b}	34.34
Control	0.00 (0.52)^{e}	0.00 (0.52)^{f}	0.00 (0.52)^{e}	0.00 (0.52)^{f}	0.00 (0.52)^{e}	0.00

sorghum/sorghum flour followed by wheat flour. Further, wheat flour had effectively attracted more *S. oryzae* as compared to other food attractants. Similar trend was noticed by Barrer (1983) who demonstrated odour-based host searching behaviour of *Cryptolestes ferrugineus, R. dominica, T. castaneum, Carpophilus dimidiatus, Typhaea stercorea*, and *Ahasverus advena,* where all of them were attracted by the trap odour emanated from wheat. The cracked wheat alone attracted *Sitophilus zeamais* six times more than *S. oryzae* (Likhayo and Hodges 2000).

Maximum attraction index for *R. dominica* was observed in the cracked sorghum (25.09% at 5 DAP). Significantly less catches with cracked corn (7.84%) and pearl millet flour (6.71%) could also be noticed (Table 1). The rice bran was found to be least effective (2.87%) in the attraction of *R. dominica*. By 10 DAP the attraction index of *R. dominica* trapped were in descending order with cracked sorghum (18.36%) > wheat flour (11.69%) > cracked corn (9.41%) > rice bran + rice flour (9.32%). The attraction of *R. dominica* to crushed groundnut (6.85%) was on par with pearl millet flour (6.48%) and sorghum flour (6.12%). The least effective attraction was found in rice bran 2.92% (Table 1). The greater trap catches of 13.53% was observed in cracked sorghum followed by wheat flour (11.63%), pearl millet flour (10.12%) at 15 DAP. The least trap catches were observed in rice flour (4.14%). Subramanyam et al. (1992) reported that cracked wheat or cracked corn could be used for detecting *S. oryzae.* Likhayo and Hodges (2000) reported that combination of cracked wheat and pheromone had an additive effect on trapping of *S. zeamais* and *S. oryzae.*

Attraction index of *Tribolium* spp. with various food bait attractant is given in Table 1. The perusal of result table showed 11.94%, 10.32%, 8.49% and 6.39% relative attraction index (RAI) of higher *Tribolium* spp. in sorghum flour, wheat flour, crushed groundnut and cracked corn respectively, at 5 DAP was registered the trend of attraction index of sorghum flour was on par with crushed groundnut. Similarly, wheat flour and rice bran + rice flour was also on par with each other at 10 DAP. The results obtained on the attraction of *S. oryzae* to different food baits showed the highest catch of 11.29% occurred in cracked sorghum at 5 DAP, while the attraction index of rice bran + rice flour, crushed groundnut, wheat flour, cracked corn, sorghum flour, pearl millet flour, rice bran was on par with each other at 5 DAP (Table 1). The bait traps filled with wheat flour and sorghum flour respectively collected 16.94 % and 13.24% of *S. oryzae* and both were on par with each other at 10 DAP, but differed significantly from other food baits. Similarly, at 15, 20 and 25 DAP the attraction index of both wheat flour and sorghum flour was on par with each other but differing significantly from other food baits.

The results of *O. surinamensis* attraction index presented in the Table 2. At 5 DAP, the highest attraction was observed in pearl millet flour (22.13%) followed by sorghum flour (9.36%) which was on par with wheat flour (7.94%), cracked sorghum (7.19%) and rice bran (6.49%). The least attraction was observed in rice flour with 2.59%. At 10 DAP, highest attraction was observed in pearl millet flour (16.90%) followed by sorghum flour (7.97%), which was statistically equivalent with wheat flour (6.42%) and cracked sorghum (6.87%). The least attraction was observed in rice flour (1.21%). At 15 DAP the highest attraction was observed in pearl millet flour (18.92%) followed by sorghum flour (12.21%) and the least attraction was noted in cracked corn 2.79% and rice flour 3.68% as both were on par with each other. At 20 DAP the highest attraction was observed in pearl millet flour (12.31%) followed by sorghum flour (8.20%) and the least attraction was occurred with cracked corn (3.56%) which was statistically identical with rice flour and rice flour + rice bran. At 25 DAP the highest

Table 2. Behavioural/ orientation response of *Tribolium* spp., *S. oryzae* and *R. dominica* to food attractants

S. No.	Food attractants	* *Tribolium* spp. settled (%)				*S. oryzae* settled (%)				*R. dominica* settled (%)			
		5 MAR**	10 MAR	15 MAR	20 MAR	5 MAR	10 MAR	15 MAR	20 MAR	5 MAR	10 MAR	15 MAR	20 MAR
1	Wheat flour	35.33 (36.47) ^{a}	25.33 (30.22) ^{a}	30.00 (33.21) ^{a}	40.00 (39.23) ^{a}	20.00 (26.57) ^{bc}	28.00 (31.95) ^{a}	32.00 (34.45) ^{a}	31.33 (34.04) ^{a}	22.00 (27.97) ^{b}	30.00 (33.21) ^{a}	34.00 (35.67) ^{a}	28.00 (31.95) ^{a}
2	Sorghum flour	24.00 (29.33) ^{b}	26.00 (30.66) ^{a}	26.00 (30.66) ^{a}	22.00 (27.97) ^{b}	26.00 (30.66) ^{b}	21.33 (27.51) ^{b}	16.00 (23.58) ^{b}	26.00 (30.66) ^{ab}	14.67 (22.52) ^{c}	26.00 (30.66) ^{ab}	20.00 (26.57) ^{c}	24.00 (29.33) ^{a}
3	Pearl millet flour	14.67 (22.52) ^{c}	20.00 (26.57) ^{a}	16.00 (23.58) ^{b}	13.33 (21.42) ^{c}	14.00 (21.97) ^{c}	16.00 (23.58) ^{c}	20.00 (26.57) ^{b}	16.00 (23.58) ^{c}	14.00 (21.97) ^{c}	12.00 (20.27) ^{c}	26.00 (30.66) ^{b}	18.00 (25.10) ^{b}
4	Control (without food)	4.67 (12.48) ^{d}	3.33 (10.52) ^{b}	4.00 (11.54) ^{c}	2.67 (9.40) ^{d}	4.67 (12.48) ^{d}	4.67 (12.48) ^{d}	4.00 (11.54) ^{c}	4.00 (11.54) ^{d}	4.00 (11.54) ^{d}	7.33 (15.71) ^{d}	2.67 (9.40) ^{d}	5.33 (13.35) ^{c}
5	Unsettled	21.33 (27.51) ^{b}	25.33 (30.22) ^{a}	24.00 (29.33) ^{a}	22.00 (27.97) ^{b}	35.33 (36.47) ^{a}	30.00 (33.21) ^{a}	28.00 (31.95) ^{a}	22.67 (28.43) ^{b}	45.33 (42.32) ^{a}	24.67 (29.78) ^{b}	17.33 (24.60) ^{c}	24.67 (29.78) ^{a}

*Mean of four replications; **MAR- Minutes after release; Values in parentheses arcsine transformed values; Means followed by same letter (s) in a column not significantly different by DMRT (p=0.05)

attraction was observed in pearl millet flour (11.65%) followed by rice bran (7.16%) which was on par with wheat flour, sorghum flour and cracked sorghum. The least attraction was occurred in cracked corn (2.10%) which was statistically on par with rice flour.

Considering the overall total attraction index of different food bait tested, pearl millet flour recorded the highest attraction (81.91%) followed by sorghum flour (44.61%), wheat flour (35.99%), cracked sorghum (34.34%) and the least attraction was observed in rice flour 12.64% (Table 2). The maximum attraction of *O. surinamensis* was due to some odours produced by pearl millet flour followed by wheat flour. The results are in line with the earlier findings in which *O. surinamensis* had been attracted to cracked corn or rolled oats (Subramanyam, 1992). *T. confusum* and *S. oryzae* responses to plant extracts and pheromones were examined by (Athanassiou et al., 2006), who found that traps with baits like oil and seeds are more attractive than traps without bait. Cracked wheat was found to be more attractive than wheat germ oil, whole wheat (Walgenbach et al., 1987). Based on the observation made in four arm olfactometer maximum preference of *Tribolium* spp. was recorded in wheat flour (35.33%) followed by sorghum flour (24%) and pearl millet flour 14.67% at 5 min after release (MAR). By the end of 25 MAR, the highest attraction was found to be in the arm containing wheat flour (36.67%) succeeded by pearl millet flour (22%) and sorghum flour (20%) (Table 2).

Olfactometer bioassay showed that at 5 MAR more *S. oryzae* (26%) settled in the test arm containing sorghum flour which was on par with wheat flour. At 20 MAR, the *S. oryzae* was significantly attracted to the arm containing wheat flour which was on par with sorghum flour. Olfactometer bioassay revealed the significant variations on orientation/behavioural response of *R. dominica* towards wheat flour, sorghum flour, pearl millet flour and control (without food bait) in a four-arm olfactometer. At 5 min after release (MAR), the highest orientation of 22% recorded towards wheat flour and found significantly superior to other flours followed by sorghum flour (14.67%) and pearl millet flour (14%), which are on par with each other. *R. dominica* was oriented towards wheat flour (28%), which was on par with sorghum flour (24%) at 20 MAR (Table 2). In the current study, highest visits or entries of *R. dominica* towards the wheat flour was (32%) and (39%) at 15 and 25 min after release (MAR) respectively, and sorghum flour with (26%)

and (26%) at 5 and 20 MAR, respectively, which are comparable with earlier works. Behavioural response of *R. dominica* to host plant (maize grain and winter wheat grains) bioassay indicated that both male and female *R. dominica* attracted to maize and wheat grain than the control (Ukeh and Umoetok 2007). Dowdy et al. (1993) reported that 9.8% of *R. dominica* oriented towards clean wheat compared to infested wheat (64.7%). The current findings are consistent with those of Edde and Phillips (2006), who found that 82% of *R. dominica* beetles have the greatest response to food volatile. According to (Nguyen et al., 2008), only 37% of *R. dominica* arrived at the clean wheat, brown rice, or maize, while 80% were able to locate the infested wheat.

Among the three food baits tested, the highest attraction was found to be in the arm containing wheat flour 40% and 37% to *Tribolium* spp. at 20 and 25 MAR, respectively. According to (Dukic et al., 2020), who investigated in a two-way olfactometer that the distribution of adult *T. castaneum* towards infested and uninfested grains was observed to be significantly higher on the wheat bran infested with their nonspecific than on the uninfested wheat bran. *T. castaneum* larvae and adults were attracted to the odours of wheat flour or whole wheat grain (Stevenson et al., 2017) is comparable with the present investigation. Vijay et al. (2020) reported that the highest orientation of *S. oryzae* was recorded towards sorghum (53.33%) in 20 MAR. While in our study the highest orientation of *S. oryzae* towards wheat flour was 31% and 39% of 20 and 25 MAR, respectively, while 26% of *S. oryzae* settled in sorghum flour at both 5 and 20 MAR. According to Trematerra et al. (2000), *O. surinamensis*, *T. castaneum*, and *T. confusum* use grain volatile odours to determine whether stored wheat grain kernels have been damaged mechanically or by insects and these studies are corroborative to the present findings. Wheat germ extracts are more attractive than other fractions, while fermented millet flour or whole millet flour volatiles are more attractive than whole millet kernels or millet starch (Seifelnasr et al., 1982).

ACKNOWLEDGEMENTS

The authors thank the Department of Agricultural Entomology, Agricultural College and Research Institute, Madurai. TNAU for providing adequate laboratory and field research facilities.

AUTHOR CONTRIBUTION STATEMENT

The study was conceptualised and designed by J Jayaraj and M Shanthi. M Sathiyaseelan carried out the experiments and prepared the manuscript. K Sujatha assisted with the storage grain sample collection and data analysis. The article was read and approved by all the authors.

FINANCIAL SUPPORT

This research received no external funding.

CONFLICT OF INTEREST

No conflict of interest.

REFERENCES

Ahmad F, Ridley A W, Daglish G J, Burrill P R, Walter G H. 2013. Response of *Tribolium castaneum* and *Rhyzopertha dominica* to various resources, near and far from grain storage. Journal of Applied Entomology 137(10): 773-781.

Athanassiou G C, Nickolas G K, Pasquale Trematerra. 2006. Responses of *Sitophilus oryzae* (Coleoptera: Curculionidae) and *Tribolium confusum* (Coleoptera: Tenebrionidae) to traps baited with pheromones and food volatiles. European Journal of Entomology 103(2): 371.

Barrer P M. 1983. A field demonstration of odour-based, host-food finding behaviour in several species of stored grain insects. Journal of Stored Products Research 19 (3): 105-110.

Bashir T, Birkinshaw L A, Hall D R, Hodges R J. 2001. Host odours enhance the responses of adult *Rhyzopertha dominica* to male produced aggregation pheromone. Entomologia Experimentalis et Applicata1 01(3): 273-280.

Dowdy A K, Howard R W, Seitz L M, McGaughey W H. 1993. Response of *Rhyzopertha dominica* (Coleoptera: Bostrichidae) to its aggregation pheromone and wheat volatiles. Environmental Entomology 22(5): 965-970.

Dukic, Nikola, Goran Andrić, Velemir Ninkovic, Marijana Pražić Golić, Petar Kljajić, Andja Radonjić. 2020. Behavioural responses of *Tribolium castaneum* (Herbst) to different types of uninfested and infested feed. Bulletin of Entomological Research 110(4): 550-557.

Edde P A, Phillips T W. 2006. Potential host affinities for the lesser grain borer, *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae): behavioral responses to host odors and pheromones and reproductive ability on non-grain hosts. Entomologia Experimentalis et Applicata 119: 255-263.

Likhayo P W, Hodges R J. 2000. Field monitoring *Sitophilus zeamais* and *Sitophilus oryzae* (Coleoptera: Curculionidae) using refuge and flight traps baited with synthetic pheromone and cracked wheat. Journal of Stored Products Research 36(4): 341-353.

Mohan S. 1993. Studies on detection and management of stored product insect pests of rice. Tamil Nadu Agricultural University, Coimbatore.

Nguyen D T, Hodges R J, Belmain S R. 2008. Do walking *Rhyzopertha dominica* (F.) locate cereal hosts by chance? Journal of Stored Products Research 44(1): 90-99.

Prakash A, Kauraw L P. 1982. Studies on insects, mites and fungal infestation in rural and farm stored rice in Orissa. Journal of Research, Assam Agricultural University 3(2): 190-196.

Rietdorf K, Steidle J L M. 2002. Was Hopkins right? Influence of larval and early adult experience on the olfactory response in the granary weevil *Sitophilus granarius* (Coleoptera, Curculionidae). Physiological Entomology 27(3): 223-227.

Rizana M M, Phillips T W. 2007. Orientation of the cigarette beetle, *Lasioderma serricorne* (F.) (Coleoptera: Anobiidae) to plant-derived volatiles. Journal of Insect Behavior 20(1): 99-115.

Seifelnasr Y E, Hopkins T L, Mills R B. 1982. Olfactory responses of adult *Tribolium castaneum* (Herbst), to volatiles of wheat and millet kernels, milled fractions, and extracts. Journal of Chemical Ecology 8(12): 1463-1472.

Smith M. Charles, Khan R, Pathak M D. 1993. Techniques for evaluating insect resistance in crop plants: CRC press.

Stevenson B J, Cai L, Faucher C, Michie M, Berna A, Ren Y, Anderson A, Chyb, Xu W. 2017. Walking responses of *Tribolium castaneum* (Coleoptera: Tenebrionidae) to its aggregation pheromone and odors of wheat infestations. Journal of Economic Entomology 110(3): 1351-1358.

Subramanyam B H. 1992. Relative retention of adult sawtoothed grain beetles in potential food baits. Postharvest Biology and Technology 2(1): 73-82.

Subramanyam B H, Wright V F, Fleming E E. 1992. Laboratory evaluation of food baits for their relative ability to retain three species of stored-product beetles (Coleoptera). Journal of Agricultural. Entomology 9(2).

Trematerra P, Sciarreta A, Tamasi E. 2000. Behavioural responses of *Oryzaephilus surinamensis*, *Tribolium castaneum* and *Tribolium confusum* to naturally and artificially damaged durum wheat kernels. Entomologia Experimentalis et Applicata 94(2): 195-200.

Ukeh D A, Umoetok S B A. 2007. Effects of host and non-host plant volatiles on the behavior of the Lesser Grain Borer, *Rhyzopertha dominica* (Fab.). Journal of Entomology 4 (6): 435-443.

Vijay S, Bhuvaneswari K, Baskaran V, Mary Lisha J. 2020. Olfactometer studies of *Sitophilus oryzae* L. feeding on sorghum and split pulses. Journal of Entomology and Zoology Studies 8(4).

Walgenbach A C, Burkholder W E, Curtis M J, Khan Z A. 1987. Laboratory trapping studies with *Sitophilus zeamais* (Coleoptera: Curculionidae). Journal of Economic Entomology 80(4): 763-767.

(Manuscript Received: February, 2024; Revised:June, 2024;
Accepted: July, 2024; Online Published: July, 2024)
Online First in www.entosocindia.org and indianentomology.org Ref. No. e24020