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A Comparative Study on Host Range of *Tribolium castaneum* (Herbst) and *Rhyzopertha dominica* (Fabricius) to Cassava (*Manihot esculenta* Crantz) and Selected Stored Grains

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Abstract

Host range of *Tribolium castaneum* and *Rhyzopertha dominica* to cassava chips were compared with stored grains such as wheat, black gram and rice. Test insects (20 Nos., 1M: 1F) were reared in splintered and flour forms of host samples under laboratory conditions. The parental adults were removed after 10th day of exposure and emergence of grub was noticed. Flour forms of wheat, black gram, rice and cassava were found more suitable for the adult emergence of *T. castaneum* whereas *R. dominica* preferred whole and broken forms of selected food except cassava. The number of adult emergence of *T. castaneum* and *R. dominica* was higher in wheat flour (67.4±6.2) and whole form of black gram (164.2±4.7) respectively. In the case of *T. castaneum,* the number of adult emergence was 51.8±5.8 and 57.6±2.0 in flours of black gram and rice respectively, whereas it decreased to 5.4±1.5 and 5.0±1.5 in whole forms of black gram and rice respectively. In the case of *R. dominica,* the number of adult emergence was 147.0±6.1 and 67.0±3.5 in whole forms of wheat and rice whereas it was only 11.6±2.0 and 12.8±2.7 when reared in flour forms of wheat and rice respectively. Among all the selected forms of cassava, only the flour forms supports the adult emergence of *T. castaneum* and *R. dominica*.

Key words: Host preference, *Tribolium castaneum, Rhyzopertha dominica, Manihot esculenta*

Introduction

Qualitative and quantitative deterioration in stored-products by a spectrum of pests is a challenge to mankind. Globally, almost one thousand species of insect pests have been associated with stored products (Srivastava and Subramanian, 2016) with major or minor status; of these *Tribolium castaneum* (Herbst) and *Rhyzopertha dominica* (Fabricius) are categorised as the most serious pests that multiplies very fast (Haines, 1991; Karunakaran et al., 2004; Amjad Ali et al., 2009; Din et al., 2018) feed and contaminate the stored grains (Hodges et al., 1996).

Depending on the distribution and abundance of availability, a wide range of grains and milled products are access to *T. castaneum*. Shafique et al., (2006) and Ahmad et al., (2012) observed highest number of larvae in the flour of wheat and sorghum than their whole and kibbled forms. Nadeem et al., (2011) screened the relative food preference and developmental period of *T. castaneum* on paddy, brown and milled rice under laboratory conditions and the beetle preferred paddy to brown and milled rice for oviposition, whereas the larvae developed to adults only in brown rice as it could not feed on rice kernel by boring through the tough siliceous hull of paddy (Cogburn, 1985). Din et al., (2018) reported that progeny production was significantly higher in wheat than rice and maize.

Volatiles derived from rice, soybean, oat, wheat germ, and corn have a pivotal role in attracting adults (Phillips et al., 1993). Bergerson and Wool (1987) compared the host preference of 12 laboratory strains and a hybrid strain of *T. castaneum* in four diets such as wheat flour, wheat germ, powdered rice, and corn flour, and found that the pest preferred wheat flour as a confirmed host for survival and reproduction over 16 generations. Wheat flour supplemented with 5% Brewer's yeast is considered as a standard medium for the development and maintenance of *T. castaneum* culture in the laboratory (Khattak et al., 1986). Levinson (1978) demonstrated that chemo-signal extracted from wheat-germ in different solvents stimulated beetles to feed. Sugars alone or in combination with other substances like lipid components, specifically palmitic acid and triglycerides in the extracts of germinating wheat act as phagostimulant that elicit aggregation of adult *T. castaneum* (Loschiavo, 1965).

Rhyzopertha dominica, a highly polyphagous pest (Wright et al., 1990; Potter, 1935) feeds mostly on grains from families belong to poeaceae (e.g. rice, wheat, sorghum, oats, pearlmillet, malt, barley) and Fabaceae (e.g. chickpea, peanut, beans) (Edde and Phillips 2006; Perisiæ et al., 2018). Rearing *R. dominica* in wheat, barley, rye, oats and triticale, revealed triticale was the most suitable host, whereas rearing in oats caused high mortality rate and lowest progeny production (Perisiæ et al., 2018).

Nadeem et al., (2011) studied the feeding and oviposition of *R. dominica* among paddy, brown and milled rice of varieties IR-6, NIAB-IRRI-9, Basmati-370 and DM-25 under laboratory conditions and found the beetle preference to brown rice to milled rice and paddy. Similar observations were also made by Cogburn, (1977) that rough or brown rice were more suitable for *R. dominica*. Bashir et al., (2001) and Edde and Phillips (2006) described the influence of volatiles on the attraction of *R. dominica* to its food source. Former examined the response of beetle to the volatiles of maize and established males are more attracted than females to their host. Females would locate the food source by following the pheromone signals produced by males. Edde and Phillips (2006) compared the behavioural response of male and female beetle to the volatiles of wheat, peanut, cowpea, potato tubers, acorns and twigs from cedar and pine. The beetle showed a strongest response to wheat volatiles and high reproductive rate than volatiles from other selected hosts.

Physical properties of grains have a significant role in host preference. Kavallieratos et al., (2010) and Keskin and Ozkaya (2013) reported that high grain hardness, smaller size and kernel shape could discourage *R. dominica* from laying eggs in clusters on the grain. But Giles et al., (2000) compared the progeny production of the beetle with kernel size of same wheat cultivar and suggested that larger quantities of progeny was produced on small kernels compared with large kernels. Locatelli et al., (2019) also supported this as they found highest number of adult emergence from maize with hard kernels and vitreous endosperm, which is rich in proteins, at the periphery of the kernels. Texture of food is also having an influence on the development of larva. Howe (1950) found that the larval period was 50 days in wheat flour whereas it was 35 days for the beetle reared in wheat kernels at 28^{o} C and 70% RH.

Cassava, *Manihot esculenta* Crantz, cultivated mainly for its tubers as staple or subsidiary food for 700 million people. Tubers are used for the production of starch, sago, ethanol and high fructose syrup, and also a major component as animal, fish and poultry feed (FAO, 1990). Lack of non-starchy constituents such as protein and lipid in tubers makes easy for its starch extraction. Normally fresh cassava tubers cannot be stored without spoilage for more than 3-5 days. In order to overcome this problem the conventional practice among the farmers is slicing the fresh tubers into small pieces and sun-drying them. These chips are more stable and can be stored for longer periods. Cassava chips are vulnerable to insect infestation and as many as 21 insect species have been associated with stored chips in India (Anon. 1991). The current study reports host preference of *T. castaneum* and *R. dominica* to cassava chips in comparison with other selected stored grains.

Materials and Methods

(a) Maintenance of insect culture

Tribolium castaneum and *R. dominica* obtained from infested food grains collected from grocery markets in Thiruvananthapuram district were reared in the

Biopesticide laboratory of ICAR-Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram at 32 ± 2°C and RH 70 ± 5% over their respective diets in a plastic container of 500 ml capacity. Mouth of the container was closed with a muslin cloth to ensure aeration.

(b) Host preference

Fresh samples of wheat, black gram and rice collected from the market were washed in water and dried to ensure the removal of pesticide residues if any. Dried cassava chips were given as a new host for the test insects. Splintered and flour forms of host samples were also used to check the host preference. Uniform populations of test insects were maintained in laboratory culture. Known quantity (20gm) of food samples along with 20 numbers of adults with 1:1 male and female ratio was taken in a 100 ml plastic container and those were covered with perforated lid. The grains were separated from the parental adults on the 10th day of exposure,and the emergence of grub was noticed every day. Newly emerged larva was transferred from the primary culture to a new container with their respective food to record the further development. The experiment was replicated five times. Since the average duration of egg to adult development of both insects varied between eight-nine weeks (Shafique et al. 2006; Nadeem et al. 2011; Edde 2012.), twelve weeks were chosen for incubation as duration of development might extend longer in non-preferred commodities. Damaged grains and dust were weighed separately to assess the quality and quantity deterioration of the food provided.

Results and Discussion

Wheat flour was found to be the most suitable host as on an average 70.4 ± 5.3 larvae emerged from this host as against 0.2 ± 0.4h from cassava chips (Table1) when 10 pairs of *T. castaneum* were released. Broken wheat supported the emergence of 64.6 ± 5.8 larvae followed by whole wheat (58.2 ± 4.1). Whereas in the case of black gram, larval emergence was higher (60.8 ± 5.2) in broken grain followed by flour (58.2 ± 6.0) and whole grains (56.6 ± 3.5). In rice, flour supported the emergence of 67.8 ± 2.5 larva followed by broken (49.6 ± 2.9) and whole grain (43.8 ± 3.1). Among all the selected food, flour was found to be the most suitable for adult emergence of *T. castaneum* (Fig. 1). Of the food sources selected, wheat flour was found to support highest (67.4) adult emergence followed by the flours of rice (57.6), black gram (51.8) and cassava (21.8). There was no emergence observed in both broken and whole forms of cassava chips.

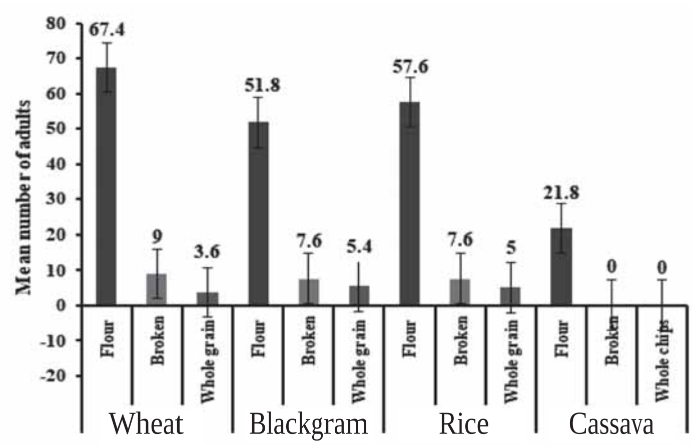

Fig. 1. Adult emergence of *Tribolium castaneum* in selected food hosts

Unlike *T. castaneum*, *R. dominica* preferred broken and whole grains than flours. Whole grain of black gram was found to be the most preferable host as the larval emergence was 172.6 ± 3.3 from 10 pairs (Table 1). There was no significant difference obtained in the larval emergence between whole and broken forms of black gram. In the case of wheat, the highest larval emergence was obtained from whole grain (159.0 ± 7.2) followed by broken (133.8 ± 8.1) and flour (40.2 ± 4.3). But in the case of rice, the highest number of larva was emerged from broken rice (103.0 ± 11.4) than whole grain (82.0 ± 5.0) followed by flour (39.0 ± 3.1). *R. dominica* reared in flour and broken forms of cassava shows the least number of adult emergence as 15.0 ± 1.8 and 2.2 ± 1.9 respectively. In contrast, no emergence was obtained from the whole chips of cassava. Development of larva to adult was considerably decreased in flour forms of selected hosts. The highest number of adult was obtained from whole grains of black gram (164.2) (Fig. 2) followed by broken form of the same (148.8).

The Duncan's Multiple Range Test ($P < 0.05$) was used and the significant differences in each column are indicated by different

Table 1. Emergence of *Tribolium castaneum* and *Rhyzopertha dominica* from selected hosts

Food host	Emergence							
	Tribolium castaneum				*Rhyzopertha dominica*			
	Larva	Pupa	Adult	Sex Ratio (M:F)	Larva	Pupa	Adult	Sex Ratio (M:F)
WF	70.4 ± 5.3^{a}	68.6 ± 6.3^{a}	67.4 ± 6.2^{a}	0.78:1	40.2 ± 4.3^{f}	13.8 ± 3.1^{i}	11.6 ± 2.0^{g}	0.49:1
WB	64.6 ± 5.8^{bc}	15.2 ± 1.9^{ef}	9.0 ± 1.5^{e}	0.36:1	133.8 ± 8.1^{c}	125.8 ± 8.9^{d}	121.8 ± 8.3^{c}	0.74:1
WW	58.2 ± 4.1^{d}	6.6 ± 1.5^{g}	3.6 ± 1.8^{gh}	0.29:1	159.0 ± 7.2^{b}	150.0 ± 7.3^{c}	147.0 ± 6.1^{b}	0.79:1
BGF	58.2 ± 6.0^{d}	55.0 ± 6.7^{c}	51.8 ± 5.8^{c}	0.63:1	45.2 ± 3.7^{f}	29.4 ± 3.2^{g}	22.4 ± 2.0^{f}	0.56:1
BGB	60.8 ± 5.2^{cd}	17.6 ± 2.7^{e}	7.6 ± 1.8^{ef}	0.73:1	167.0 ± 7.5^{a}	160.4 ± 6.1^{b}	148.8 ± 6.1^{b}	0.71:1
BGW	56.6 ± 3.5^{d}	15.2 ± 1.9^{ef}	5.4 ± 1.5^{efg}	0.5:1	172.6 ± 3.3^{a}	$168.0^{a} \pm 4.6$	164.2 ± 4.7^{a}	0.77:1
RF	67.8 ± 2.5^{ab}	63.4 ± 2.5^{b}	57.6 ± 2.0^{b}	0.8:1	39.0 ± 3.1^{f}	23.2 ± 3.5^{gh}	12.8 ± 2.7^{g}	0.64:1
RB	49.6 ± 2.9^{e}	12.2 ± 1.9^{f}	7.6 ± 1.1^{ef}	0.46:1	103.0 ± 11.4^{d}	93.6 ± 11.5^{e}	89.4 ± 12.9^{d}	0.75:1
RW	43.8 ± 3.1^{f}	5.6 ± 1.9^{g}	5.0 ± 1.5^{fg}	0.32:1	82.0 ± 5.0^{e}	72.8 ± 3.1^{f}	67.0 ± 3.5^{e}	0.9:1
CF	32.6 ± 2.7^{g}	26.6 ± 3.3^{d}	21.0 ± 2.5^{d}	0.63:1	29.2 ± 4.1^{g}	18.2 ± 2.7^{hi}	15.0 ± 1.8^{g}	0.7:1
CB	4.0 ± 1.5^{h}	0.4 ± 0.8^{h}	-	-	10.8 ± 2.4^{h}	3.8 ± 2.7^{j}	2.2 ± 1.9^{h}	0.22:1
CW	0.2 ± 0.4^{h}	-	-	-	0.8 ± 1.3^{I}	-	-	-
p-value	$< .0001$	$< .0001$	$< .0001$		$< .0001$	$< .0001$	$< .0001$	
LSD at 5%	5.06	4.25	3.74		7.25	7.33	6.96	

WF: Wheat Flour, WB: Wheat Brocken, WW: Wheat Whole grain, BGF: Black Gram Flour, BGB: Black Gram Brocken, BGW: Black Gram Whole grain, RF: Rice, RW: Rice Brocken, RW: Rice Whole grain, CF: Cassava Flour, CB: Cassava Brocken, CW: Cassava Whole grain.

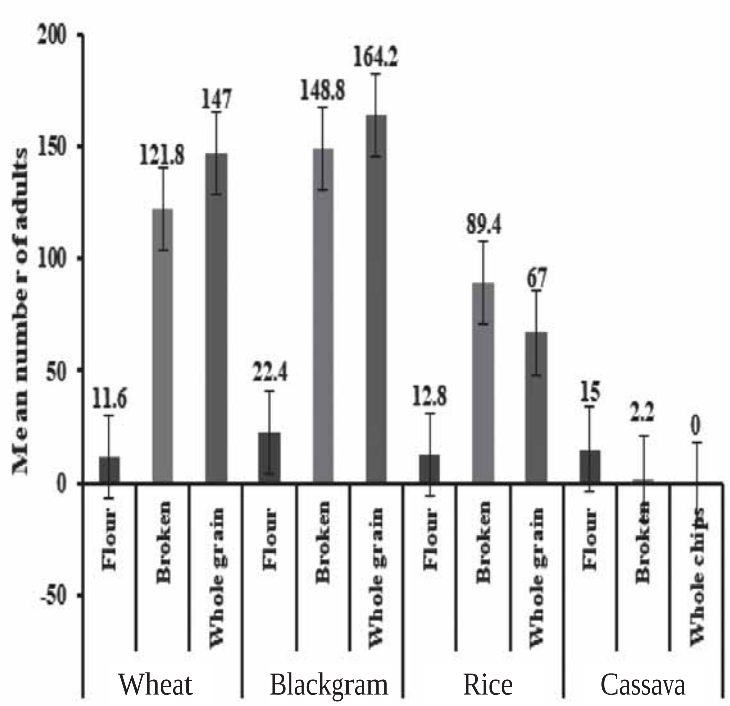

Fig. 2. Adult emergence of *Rhyzopertha dominica* in selected hosts

letters. There were five replicates for each variable.

Feeding preference and emergence of *Tribolium castaneum* in various food grains were compared previously by many researchers (Hamed 1985, Khattak et al., 1986; Shafique et al., 2006; Nadeem et al., 2011; Ahmad et al., 2012). Among rice, the insect preferred paddy to brown and milled rice for oviposition but larvae developed to adults only in brown rice. While comparing with wheat and sorghum highest number of insect of each stage was developed on wheat flour. It was observed that *T. castaneum* oviposits in all forms of selected hosts but the developmental stages were proceed progressively only in the flour forms of food.

High rate of adult emergence was obtained from flour forms of selected hosts than broken and whole grains. All forms of cassava were found to be the most undesirable host for *T.*

castaneum. Mason (2018) also reported the adult emergence was highest from wheat flour and the least emergence from whole grain. Karunakaran et al., (2004) and Devi et al., (2015) reported that both larvae and adults of *T. castaneum* feed only in flour and broken forms of grains, but not the undamaged whole grains. Shafique et al., (2006) confirmed that the development and survival rate of *T. castaneum* were significantly higher in wheat flour followed by bran, maida, suji, tempered and dry wheat. Li and Arbogast (1999) studied the emergence of *T. castaneum* in different forms of maize and concluded that development of the weevil was significantly higher in maize flour and the survival and development delayed in undamaged grains. The low moisture content in whole grains reduces *T. castaneum* population (Shafique et al., 2006). All these findings are in close conformity with the results of the current study that *T. castaneum* prefer flour for both feeding and development.

Rhyzopertha dominica reared in whole and broken forms of selected grains showed highest adult emergence in comparison with flour forms. Edde (2012) found that *R. dominica* could feed mainly on families of Poaceae and Fabaceae as larvae and pupa develops and feed on both the germ and endosperm of the whole grains. Kavallieratos et al., (2010) observed that the survial ship and fecundity of the beetle significantly decreased in smaller size and shaped kernel of grain. It was also found that the highest average emergence was obtained from the whole forms of grains especially in black gram. The study also observed that the insect oviposit on the surface of the grains and the emerged larva pores into the grains for further development. Cogburn, (1985) and Nadeem et al., (2011) studied the development and feeding preference in various rice forms and concluded that the emergence of *R. dominica* adults significantly high in whole form of rice while no larva could develop in milled rice flour.

Tribolium castaneum and *R. dominica* produce very less number of progeny in cassava flour and no significant development of progeny was obtained from the insects reared in broken and whole forms of cassava chips which indicated, among the selected food hosts, cassava is the most undesirable host for the test insects. A similar finding was obtained by Zakka et al., (2018) who studied the infestation rate of *T. castaneum* with six genotypes of cassava under laboratory conditions (25 to 30°C and 70 to 90% RH) and concluded that only cassava flour supported the growth of *T. castaneum* in comparison with cassava chips. *T. castaneum* is a secondary pest which is adapted to flour forms of host than chips or solid substrates (Lale and Ajayi, 2000; Haines, 1991; Turaki et al. 2007). *R. dominica* also exhibit a low survival and progeny production in whole form of cassava chips but can cause a considerable amount of quality loss on the cassava products (Kumar et al., 1996).

Conclusion

The host preference of *T. castaneum* and *R. dominica* towards cassava was comparatively less than other selected hosts such as wheat, black gram and rice. However, the insects are capable of posing a threat to cassava flour. *T. castaneum* preferred flour forms whereas *R. dominica* preferred whole forms of selected food grains.

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