



RESEARCH ARTICLE

Evaluation of sesame genotypes against *Tribolium castaneum*

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Abstract

Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae) is an important pest of stored sesame seeds. This research aimed to investigate the host preference, growth and development of *T. castaneum* on 30 sesame genotypes in free and no-choice tests under laboratory conditions. In the free choice test, the lowest and highest numbers of eggs were deposited on 60 KRDS and JLT-7 genotypes, respectively. The mean developmental duration was significantly extended on ES-201862 (81 days), while it was shortest on CT-35 (41 days). Simultaneously, reduced adult emergence and the lowest values of the susceptibility index were noticed on 60 KRDS. The adult survival was significantly low on CT-35 (41.50 %) and significantly high on ES-201862 (81.50 %). Similarly, in a no-choice test, fecundity, mean developmental time, adult emergence, adult survival and susceptibility index were significantly influenced by different sesame genotypes. The results of the correlation analysis indicated a non-significant relationship between the biological parameters of *T. castaneum* and the physical characteristics of the evaluated sesame genotypes. Further, cluster analysis showed that, among the sesame genotypes, PRAGATHI and EC-334997 were found to be moderately resistant genotypes, while AKT-64 was susceptible. The resistant sesame genotypes could be further evaluated to identify secondary biochemicals that contribute to *T. castaneum* resistance.

Keywords: adult emergence and survival; fecundity; mean developmental time; sesame genotypes; susceptibility index; *Tribolium castaneum*

Introduction

Sesame (*Sesamum indicum* L.) is a member of the Pedaliaceae family and is referred to as the "queen of oil seeds". Sesame seed is a common spice and a substantial source of folic acid, oil, protein, unsaturated fatty acids, vitamins and minerals. Seeds were primarily utilised in oil and wine production; they are predominantly employed for oil extraction and culinary applications (1, 2). India, Sudan, Myanmar and China account for 68 % of its global production (3). It is also used as an insecticide synergist and in pharmaceutical and skin care products (4). Because sesame seeds are high in proteins and lipids, they are vulnerable to insect pest attack. *Tribolium* spp., *Ephestia elutella*, *Plodia interpunctella* and *Corcyra cephalonica* have been identified as significant pests of oilseed storage (5). Among all the stored seed pests, the red flour beetle, *T. castaneum* Herbst (Coleoptera: Tenebrionidae) is the most common and noxious pest of sesame seed throughout the world (6). Both larva and adult of *T. castaneum* cause severe seed damage by reduction in their food quality and contamination with the insect exuviae and excreta (7). It is a common and harmful secondary pest of damaged food grain that affects both the quantity and quality of the product (8). Severe infestations cause the flour to become discoloured and mouldy, which gives it an unpleasant smell and makes it unfit for human consumption (9). Several biological characteristics, including its short lifespan, polyphagous nature, ability to compete and capacity for survival in adverse climatic conditions, make it an important pest of stored products (10).

Currently, the synthetic pesticides are the primary methods to control *T. castaneum*; however, the constant and improper use of these compounds can lead to pest resistance, environmental pollution and health hazards (6). In addition, *T. castaneum* has developed resistance to most of the registered insecticides such as phosphine, methylbromide and organophosphate (11). The application of chemical insecticides exerts detrimental consequences on both the environment and human health. The inherent ability of various sesame genotypes to withstand attack and damage caused by this insect will provide essential information for plant breeders in developing new cultivars (12). Owing to these drawbacks, new alternative methods that are less hazardous to the environment should be developed. Recently, the universal attention has been focused on the development of resistant and high-yielding cultivars. It is noticeable that the host plants with antixenosis and antibiosis mechanisms can decrease insect oviposition, survival, growth and development in the new generation adults (13).

However, limited information is available concerning the varietal preference and biology of this species on sesame genotypes. Earlier, a study showed the varietal preference of *T. castaneum* on six sesame cultivars and reported that Prachi and UMA were the least susceptible cultivars, while Subra, Vinayak, Kanak and Amrit were the most susceptible cultivars (14). Another study evaluated the life history parameters of *T. castaneum* on different sesame varieties and revealed that the longer developmental period and reduced adult emergence of *T. castaneum* were noticed in ORM-14, OS-6,

Prachi and B-67 sesame cultivars as compared to other cultivars (15). Based on this background, this study was designed to evaluate 30 genotypes of sesame for their resistance/susceptibility to *T. castaneum*.

Materials and Methods

Thirty sesame genotypes were selected to evaluate their resistance/susceptibility against *T. castaneum* and reared in the entomology laboratory at ICAR-Indian Institute of Oilseeds Research (IIOR), Hyderabad. The genotypes obtained from ICAR-IIOR seed unit were screened under free-choice tests and genotypes that were categorised as resistant and moderately resistant under the free-choice test were selected for further confirmation of resistance under a no-choice test. Physical parameters of the seed were recorded to understand the physical basis of resistance in the selected genotypes used for the no-choice test. The parameters measured included seed size (length and width), seed weight (g) and seed girth (mm). Seed length, width and girth were measured using a digital Vernier calliper and expressed in millimetres (mm). Fig. 1 represents different genotypes used in the experiment.

Insect culture

The rearing containers (18 cm diameter and 16 cm height) used for building up stock culture were cleaned with 0.5 % detergent and rinsed in tap water, followed by treatment with 2 % formaldehyde and dried. The requisite quantum of seed (2.5 kg) could be collected and heat sterilised in an oven at 100 °C for 30 min and sprayed with 0.1 % formalin to arrest the growth of moulds as well as to increase the seed which was lost due to heat sterilisation. Groundnut powder (100 g), yeast (5 g), sulphur (1 g) and streptomycin sulphate (1 g) were added to all the containers as additives. The enriching diet, such as groundnut and yeast, was added to enhance the egg-laying capacity of the adult beetle. Fifty adults of red flour beetle were placed in a basin, then lined with clean khada cloth and fastened tightly with a rubber band.

Free-choice test against *Tribolium castaneum*

The free-choice test was conducted by placing 50 seeds of each 30 accession (JLT-7, EC-334997, AVT-138-110, DSS-9, AKT-64, CT-35, PRAGATHI, TMV-4, THILOTHAMA, TKG-308, JLT-408, SAVITHRI, 60 KRDS, CT-38, TKG-22, LONGKONG, YLM-17, HIMA, JTS-8, ES-20186-2, LONGLA, RT-54, THILARANI, RT-354, SMARAK, TMV-7, PKVNT-11, RT-346, RT-46, CT-51) in 20 separate circular disk-like craters (4.5 cm diameter and 1 cm depth) carved out in the outer edge of the wooden bottom of a specially designed cylindrical cage (62 cm diameter and 16 cm height). After arranging the seeds onto the circular craters inside the cage, 50 pairs of freshly emerged adult beetles were released at the centre of the cage and covered with a muslin cloth. The insects were allowed to remain there for the purpose of oviposition for 10 days. Ten days after the release of adult beetles, seeds with eggs were recorded and transferred to a plastic box (4 cm diameter and 6 cm height). The experiment was done with two replications and data recorded on per cent adult survival, mean developmental period (MDP) and the susceptibility index as described earlier (16).

$$I = \text{Loge } F/D \times 100 \quad (\text{Eqn. 1})$$

Where, F = Total number of adults emerged, D = Mean developmental period and I = Index of susceptibility. The Howe susceptibility index, which ranges from 0 to 11, was used to

categorise sesame cultivars into susceptibility groups, where 0 to 2.5 is resistant; 2.6 to 5.0 is categorised as moderately resistant; 5.1 to 7.5 as moderately susceptible; 7.6 to 10.0 is categorised as susceptible and > 10 is categorised as highly susceptible.

No-choice test against *Tribolium castaneum*

The genotypes viz., AVT-138-110, AKT-64, CT-51, EC-334997, CT-35, RT-346, JLT-7, PRAGATHI categorised as resistant and moderately resistant under the free-choice test, were selected for further confirmation of resistance under the no-choice test with three replications in a completely randomised design. Two moderately susceptible genotypes (JLT-7, PRAGATHI) were used as a check. Three pairs of freshly emerged adult beetles were released in plastic containers containing 5 g of seed of each genotype. After 10 days, observations were recorded, which were similar to those described in the free-choice test.

Data analysis

Data was statistically analysed using MS Excel 2010 and mean separation was done using the DMRT test at 5 %. The figures were drawn in GraphPad Prism version 8.0. A dendrogram of sesame genotypes based on biological parameters of *T. castaneum* was constructed after cluster analysis by Ward's method using Past statistical software.

Results and Discussions

Free-choice test

The fecundity, developmental period, adult emergence, survival percentage and susceptibility index of *T. castaneum* reared on different sesame genotypes in the free-choice test are shown in Table 1. The fecundity of *T. castaneum* was significantly influenced by different sesame genotypes ($F = 12.91$; $df = 30$; $p < 0.05$). The minimum number of eggs was deposited on 60 KRDS (5.50 eggs/♀), which was at par with CT-38 (7.00 eggs/♀), while the maximum number of eggs was laid on JLT-7 (24.00 eggs/♀). Regarding the developmental duration of *T. castaneum*, the shortest and longest duration were observed on CT-35 and ES-201862, respectively ($F = 60.1$, $df = 30$, $p < 0.05$). Similarly, the adult emergence was significantly reduced by tested sesame genotypes ($F = 4.93$; $df = 30$; $p < 0.05$), with the lowest on 60 KRDS (3.00) and the highest on JLT-7 (13.00), respectively. Moreover, the significantly minimum survival of *T. castaneum* was noticed on TKG-22 (23.86 %) and the maximum survival was observed on AKT 64 (73.33 %). In addition, the susceptibility index of *T. castaneum* showed significantly lower values on 60 KRDS and higher values on JLT-7 ($F = 9.27$, $df = 30$, $p < 0.05$).

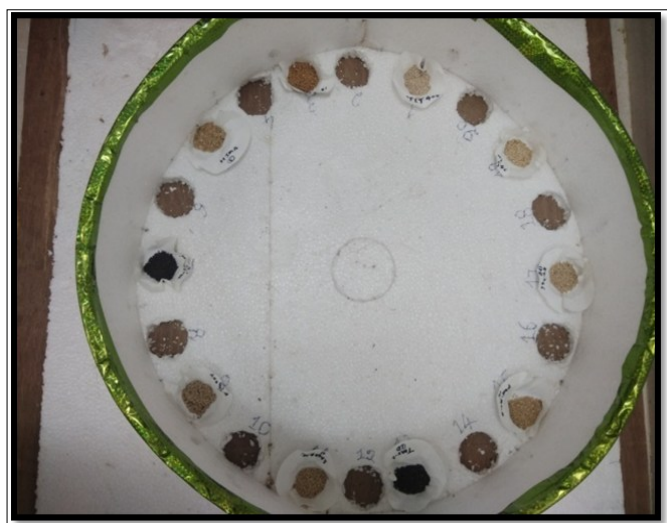
No-choice test

The biological parameters of *T. castaneum* were also significantly affected in various sesame genotypes, as shown in Fig. 2. The female that emerged from genotype CT-51 laid the lowest number of eggs as compared to other genotypes ($F = 70.04$, $df = 16$, $p < 0.05$). The shortest developmental duration was on AKT- 64 (48.00 days), JLT-7 (50.00 days), RT-346 (52.8 days) and CT-35 (53.00 days) and the longest on PRAGATHI and EC-334997 (77.00 and 73.42 days, respectively). Furthermore, the adult emergence significantly ranged from 2.85 (EC-334997) to 6.37 (AKT-64), respectively. Survival percentage of *T. castaneum* notably varied from 37.94 to 58.72 % on different sesame genotypes. With regards to the susceptibility index of *T. castaneum*, the lowest value was identified on EC-334997 (2.81)

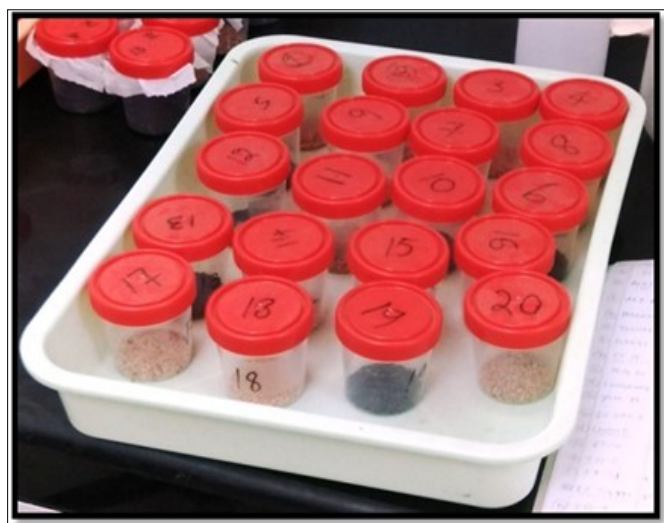
Table 1. Influence of different sesame genotypes on *Tribolium castaneum* biological traits (in free-choice test)

Sesame genotypes	Fecundity/ female *	Mean developmental period (days)*	No. of adults emerged *	Survival (%) #	Susceptibility index
JLT-7	24.00 (5.00) ^a	49.00 (7.07) ^h	13.00 (3.74) ^a	49.00 (44.43) ^j	5.23 ^a
AVT-138-110	17.00 (4.24) ^{bc}	73.50 (8.63) ^{bcd}	11.00 (3.46) ^a	73.50 (59.02) ^{de}	3.26 ^{bc}
AKT-64	9.50 (3.24) ^{efgh}	69.50 (8.40) ^{de}	7.00 (2.82) ^b	69.50 (56.48) ^f	2.78 ^{cde}
PRAGATHI	14.50 (3.94) ^{cd}	46.00 (6.86) ⁱ	10.50 (3.39) ^a	46.00 (42.71) ^k	5.11 ^a
THILOTHAMA	12.00 (3.6) ^{def}	76.50 (8.80) ^b	7.00 (2.82) ^b	76.50 (61.00) ^{bc}	2.53 ^{cdef}
60 KRDS	5.50 (2.55) ⁱ	71.00 (8.49) ^{cde}	3.00 (1.98) ^d	71.00 (57.42) ^{ef}	1.46 ^g
CT-38	7.00 (2.78) ^{hi}	69.50 (8.40) ^{de}	3.50 (2.09) ^{cd}	69.50 (56.48) ^f	1.66 ^{fg}
TKG-22	21.00 (4.69) ^{ab}	63.50 (8.03) ^f	5.00 (2.45) ^{bcd}	63.50 (52.83) ^{gh}	2.53 ^{cdef}
LONGKONG	11.00 (3.46) ^{defg}	76.50 (8.80) ^b	7.00 (2.82) ^b	76.50 (61.00) ^{bc}	2.53 ^{cdef}
YLM-17	10.00 (3.32) ^{efg}	71.00 (8.49) ^{cde}	6.00 (2.65) ^{bc}	71.00 (57.42) ^{ef}	2.52 ^{cdef}
ES-20186-2	11.50 (3.54) ^{defg}	81.00 (9.06) ^a	7.00 (2.82) ^b	81.00 (64.17) ^a	2.39 ^{cdef}
LONGLA	9.00 (3.16) ^{fgh}	71.00 (8.49) ^{cde}	4.00 (2.22) ^{bcd}	71.00 (57.42) ^{ef}	1.91 ^{efg}
RT-54	10.00 (3.32) ^{efg}	77.00 (8.83) ^b	6.00 (2.64) ^{bc}	77.00 (61.35) ^b	2.31 ^{defg}
JTS-8	9.00 (3.16) ^{fgh}	69.00 (8.37) ^e	5.00 (2.44) ^{bcd}	69.00 (56.17) ^f	2.3 ^{defg}
CT-51	8.00 (3.00) ^{ghi}	53.00 (7.35) ^g	5.00 (2.44) ^{bcd}	53.00 (46.72) ⁱ	3.01 ^{bcd}
EC-334997	13.00 (3.74) ^{cde}	73.00 (8.60) ^{bcdde}	7.00 (2.82) ^b	73.00 (58.70) ^{de}	2.65 ^{cde}
DSS-9	13.00 (3.74) ^{cde}	74.00 (8.66) ^{bc}	6.00 (2.64) ^{bc}	74.00 (59.35) ^{cd}	2.4 ^{cdef}
CT-35	11.00 (3.46) ^{defg}	41.50 (6.52) ^j	5.00 (2.44) ^{bcd}	41.50 (40.10) ^l	3.82 ^b
TMV-4	8.00 (3.00) ^{ghi}	73.50 (8.63) ^{bcd}	5.50 (2.55) ^{bcd}	73.50 (59.03) ^{de}	2.32 ^{defg}
TKG-308	10.00 (3.32) ^{efg}	65.00 (8.12) ^f	4.50 (2.34) ^{bcd}	65.00 (53.73) ^g	2.3 ^{defg}
JLT-408	9.00 (3.16) ^{fgh}	64.00 (8.06) ^f	5.00 (2.44) ^{bcd}	64.00 (53.13) ^{gh}	2.49 ^{cdef}
SAVITHRI	8.00 (3.00) ^{ghi}	54.50 (7.45) ^g	4.00 (2.24) ^{bcd}	54.50 (47.58) ⁱ	2.54 ^{cdef}
HIMA	11.00 (3.46) ^{defg}	61.50 (7.91) ^f	4.00 (2.22) ^{bcd}	61.50 (51.65) ^h	2.19 ^{defg}
THILARANI	9.00 (3.16) ^{fgh}	71.00 (8.49) ^{cde}	5.50 (2.55) ^{bcd}	71.00 (57.42) ^{ef}	2.39 ^{cdef}
RT-354	11.00 (3.46) ^{defg}	69.00 (8.37) ^e	5.00 (2.44) ^{bcd}	69.00 (56.17) ^f	2.3 ^{defg}
SMARAK	14.00 (3.87) ^{cd}	70.00 (8.43) ^{cde}	6.00 (2.65) ^{bc}	70.00 (56.79) ^f	2.56 ^{cdef}
TMV-7	21.00 (4.69) ^{ab}	69.50 (8.40) ^{de}	6.00 (2.65) ^{bc}	69.50 (56.48) ^f	2.58 ^{cde}
PKVNT-11	9.00 (3.16) ^{fgh}	74.00 (8.66) ^{bc}	6.00 (2.64) ^{bc}	74.00 (59.34) ^{cd}	2.4 ^{cdef}
RT-346	11.50 (3.53) ^{defg}	51.50 (7.25) ^{gh}	5.00 (2.44) ^{bcd}	51.50 (45.86) ^{ij}	3.08 ^{bcd}
RT-46	14.00 (3.87) ^{cd}	69.50 (8.40) ^{de}	6.00 (2.65) ^{bc}	69.50 (56.48) ^f	2.58 ^{cde}
S.Em	0.07	0.05	0.17	0.57	0.20
CD at 5 %	0.21	0.17	0.50	1.65	2.33

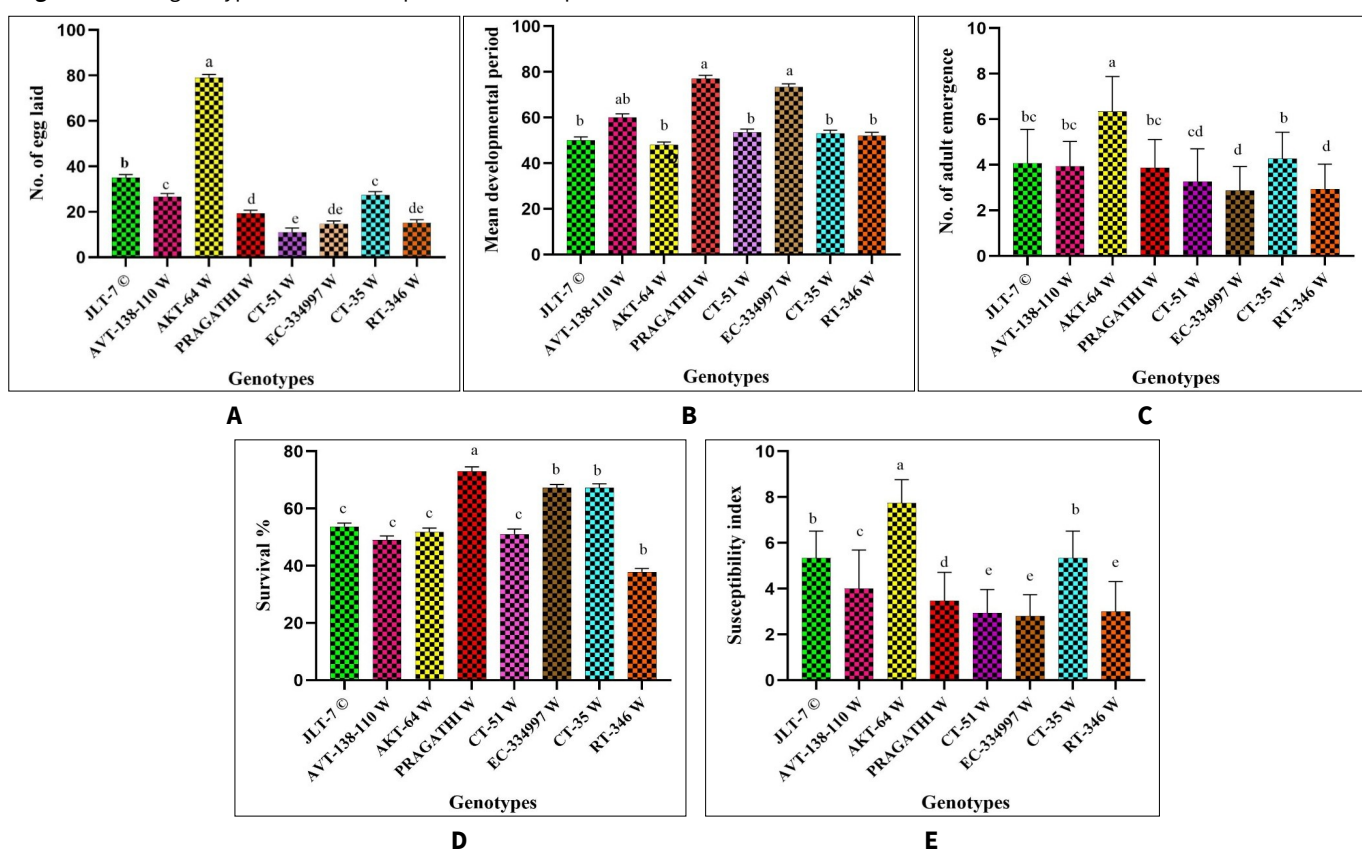
Note: Mean values within the columns bearing the same letters are non-significantly different- DMRT (5 %). *Figures in the parentheses are square root transformed values. # Figures in the parentheses are angular transformed values



Free choice cage setup



No choice cage set-up

Fig. 1. Different genotypes used in the experiment of host plant resistance.**Fig. 2.** Impact of sesame genotypes on *Tribolium castaneum* biological traits A-E (in no-choice test). A. fecundity, B. Mean developmental period, C. Number of adult emergence, D. Adult survival %, E. Susceptibility index of *Tribolium castaneum*.

and the highest value was recorded in AKT-64 (7.73). In our study, less susceptible genotypes recorded the lowest fecundity, survival, adult emergence, susceptibility index and prolonged developmental period of *T. castaneum*. These parameters exhibited a reverse trend in highly susceptible genotypes, while moderately susceptible genotypes showed intermediate reaction. Research reported that different diets significantly affect *T. castaneum* growth and development (14, 17–20). Furthermore, research also observed that the poor nutritional suitability of certain sesame varieties significantly suppresses the development and reproductive capacity of *T. castaneum* (21). Additionally, the observed effects may be attributed to the presence of antifeedant compounds, including sesamin, sesamol, phenolic compounds and flavonoids, which are

known to suppress feeding activity, reduce oviposition and enhance larval mortality (22).

A dendrogram of sesame genotypes based on the biological and physical parameters of *T. castaneum* is shown in Fig. 3. The dendrogram shows two distinct groups labelled A and B (including subgroups B1 and B2). Cluster A included (AKT-64) as a highly susceptible group; Cluster B consisted of subcluster B1 (CT-51, RT-346, CT-35, AVT-138-110 and JLT-7) as an intermediate group and B2 (PRAGATHI and EC-334997) as a least susceptible group. According to the cluster analysis results, each cluster may be grouped because of the high degree of physiological similarity between the genotypes of sesame, while the distinct clusters exhibit notable physiological feature variability.

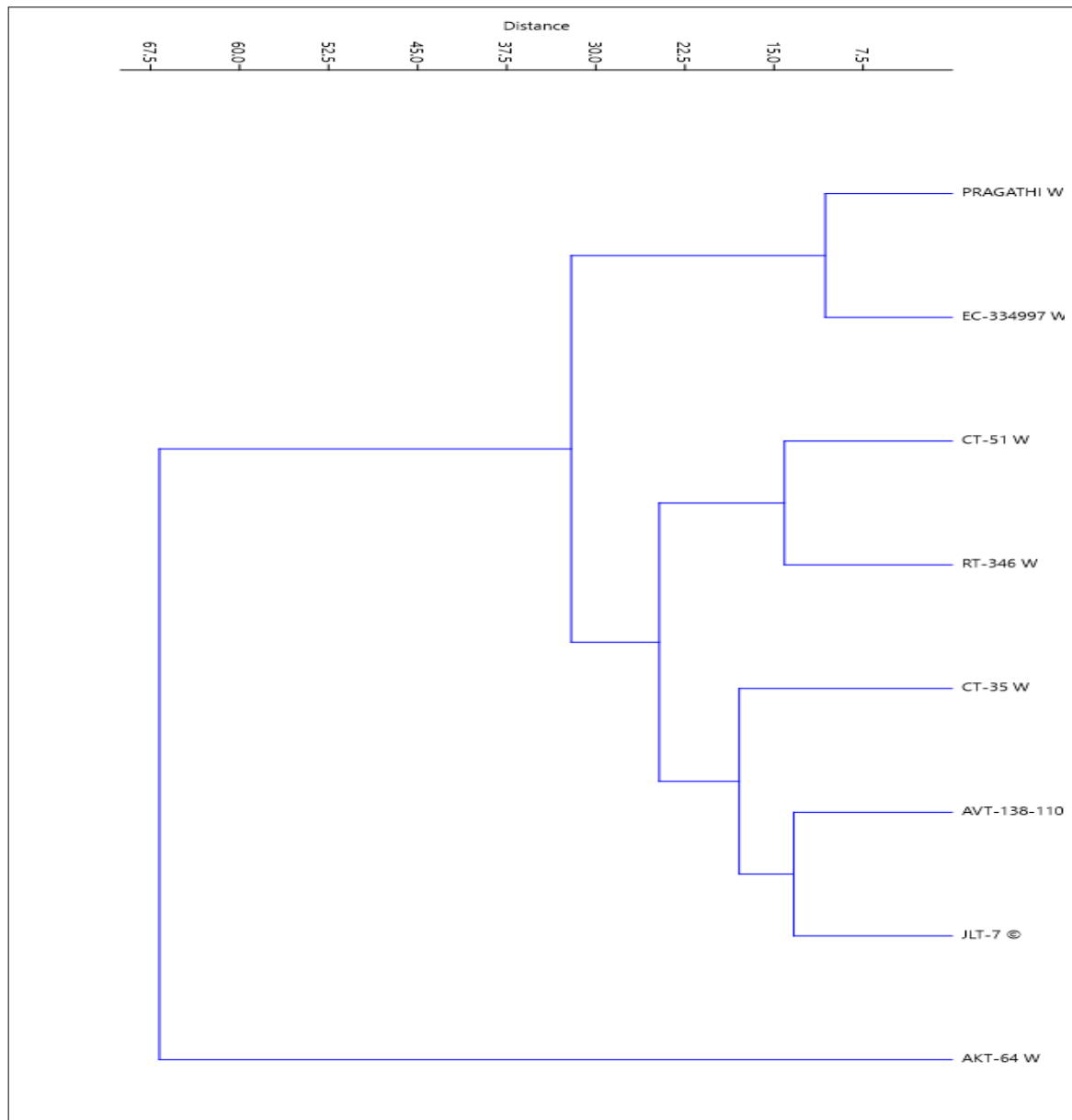


Fig. 3. Dendrogram of different sesame genotypes based on biological parameters of *Tribolium castaneum* reared on various sesame genotypes.

Table 2 shows that higher seed moisture can artificially enhance insect of sesame genotypes and test insect biological parameters (egg count, percentage survival, median development period and susceptibility index). The mean number of eggs of *T. castaneum* was positively significant with the susceptibility index, while it was negative and non-significantly correlated with survival (-0.09), MDP (-0.48) of *T. castaneum* and length (-0.25), width (-0.61), $L \times W$ (-0.51) and girth (-0.26) of sesame genotypes. Furthermore, survival, MDP and susceptibility index of the test insect did not significantly correlate with physical parameters of the tested sesame genotypes. In the present study, *T. castaneum* performance was not influenced by the physical parameters of sesame genotypes. Similarly, research indicates that the physical

traits of the seed were not significantly correlated with insect biological parameters (23). Further, research has demonstrated that in the secondary pests (*T. castaneum*), development is primarily supported by broken grain and flour, so biological parameters may exhibit a weak correlation with seed physical characteristics, as shown in Fig. 4 (24–27).

Conclusion

Based on the above results obtained from the varietal preference studies, it was evident that the biological parameters of *Tribolium castaneum* were significantly affected by the tested

Table 2. Correlation between physical characters of sesame genotypes and biological parameters of *Tribolium castaneum*

Physical parameter	Biological parameters			
	Egg count	Survival	MDP	Susceptibility Index
Length	-0.25	0.14	0.32	-0.39
Width	-0.59	0.06	0.14	-0.47
$L \times W$	-0.51	0.15	0.32	-0.53
Girth	-0.23	-0.13	0.51	-0.53
Seed weight	0.32	-0.34	-0.02	0.07

$L \times W$ - Length $\times$ Width, MDP - Mean developmental period

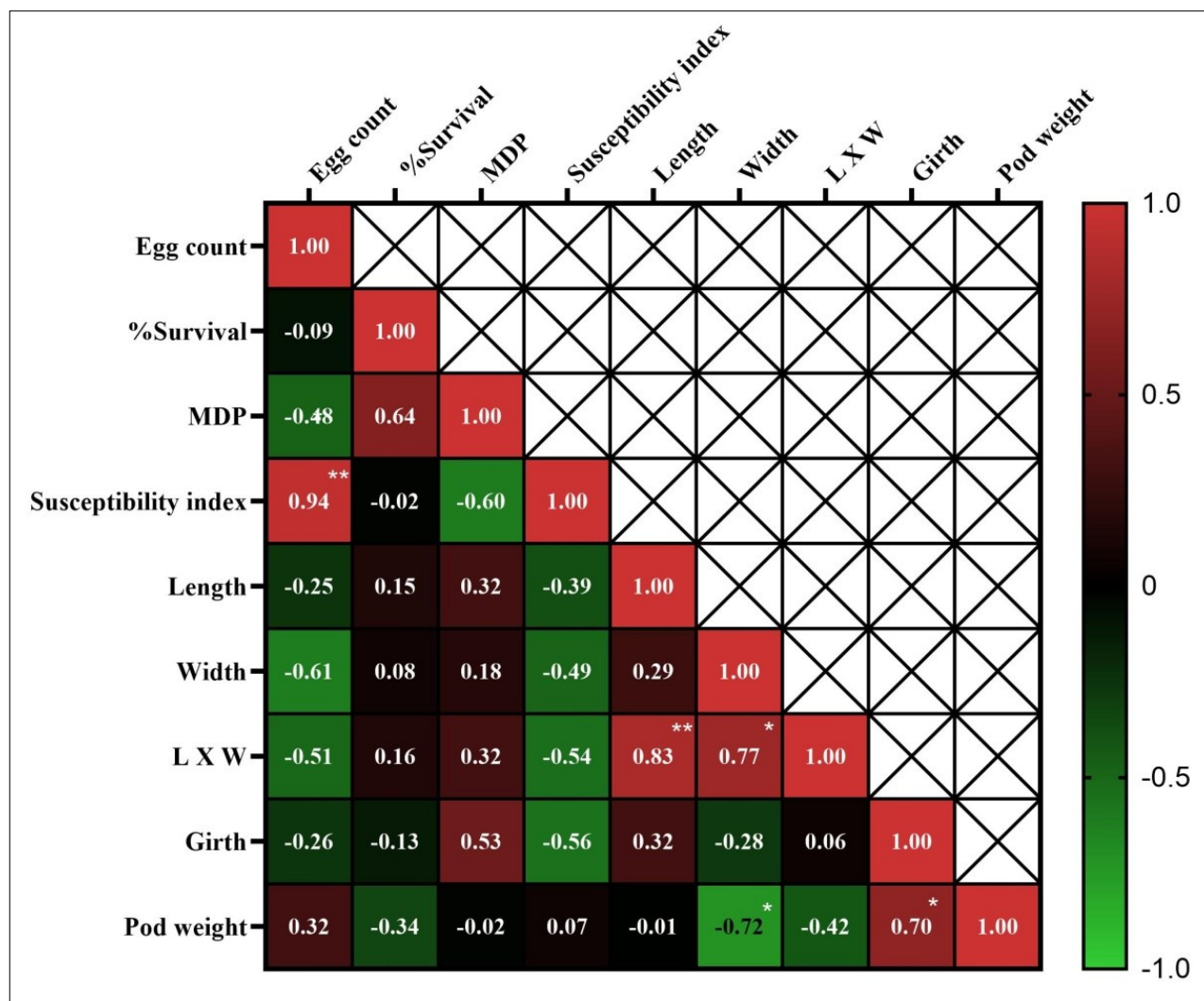


Fig. 4. Correlation heatmap of physical parameters of sesame genotypes with biological parameters of *Tribolium castaneum*.

genotypes. This information can be utilised in inheritance studies in the development of resistant varieties against the *T. castaneum*. Further studies on the nutritional and chemical composition of the sesame genotypes also help in a better understanding of the resistant mechanisms against *T. castaneum*.

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Authors' contributions

BS prepared the introduction, materials and methods and abstract. RV carried out the result interpretation, prepared the graphs and drafted the manuscript. DP revised the grammar and thoroughly verified the manuscript for technical accuracy. BAK participated in the study design and performed the statistical analysis. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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