

Resistance Assessment of Sorghum Varieties to *Tribolium castaneum* for Improved Grain Storage Management

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Abstract: The present study was conducted to assess the resistance of selected sorghum varieties against *Tribolium castaneum* under storage conditions, with the aim of improving grain storage management. Five sorghum varieties, namely CSH-16, CSH-17, CSH-6, CSH-15, and CSH-9, were evaluated through controlled laboratory bioassays over storage periods of 3, 6, 9, and 12 months. The parameters studied included insect population buildup (insects·100 g⁻¹) and percentage grain-weight loss. The results revealed a progressive increase in insect population and grain damage with the advancement of storage duration in all varieties. Among the tested varieties, CSH-17 and CSH-9 exhibited the highest insect population (420.0 ± 15.6 and 390.0 ± 14.2 insects·100 g⁻¹, respectively, at 12 months) and maximum weight loss ($29.5 \pm 1.8\%$ and $27.8 \pm 1.7\%$, respectively), indicating their susceptibility. In contrast, CSH-6 and CSH-15 showed comparatively lower infestation levels and reduced grain damage, suggesting their resistance to *T. castaneum*. CSH-16 exhibited moderate susceptibility. A strong positive correlation was observed between insect population density and grain weight loss. The study highlights the importance of varietal selection in minimizing post-harvest losses and suggests that resistant sorghum varieties can serve as an effective strategy for sustainable grain storage management.

Keywords: *Tribolium castaneum*; Sorghum varieties; Grain storage; Insect; Population dynamics; Management.

Introduction: -

Amid increasing concerns over food insecurity and the adverse impacts of climate change, greater emphasis is now being placed on crops that can tolerate harsh environmental conditions while supporting sustainable livelihoods. In recent years, ensuring food and nutritional security has become a major priority for policymakers, especially as earlier progress in addressing these issues has shown signs of reversal. Multiple global challenges,

including climate change, the COVID-19 pandemic, and rising geopolitical conflicts such as the Russia–Ukraine war and internal conflicts in countries like Ethiopia, Myanmar, Sudan, and Afghanistan, have collectively reduced access to food. This reduced accessibility is evident both in terms of physical availability and economic affordability (Rosegrant et al., 2024; Gallegos et al., 2023; Jiang et al., 2024; Yusriadi and Cahaya, 2022). Food security is closely linked with global stability and human welfare, and therefore it continues to receive considerable attention from the international research community. Although improvements have been observed in global food systems over time, a large number of countries still face serious food insecurity challenges (Xie et al., 2021).

In this context, sorghum (*Sorghum bicolor*) has emerged as an important cereal crop with the potential to address these pressing challenges (Teferra and Awika, 2019). The crop is particularly well-suited to marginal environments, especially arid and semi-arid regions where agricultural production is often constrained by erratic rainfall, frequent droughts, and low soil fertility. These conditions are typically associated with higher risks of crop failure and persistent poverty (Ashoka et al., 2020). Due to its resilience and adaptability, sorghum offers a viable pathway for addressing food insecurity, mitigating the effects of climate change, and improving agricultural productivity in regions where conventional cropping systems are failing. Globally, sorghum ranks as the fifth most important cereal crop after maize, wheat, rice, and barley in terms of both cultivation area and production (Rui-dong, 2018; Kazungu et al., 2023).

Botanically known as *Sorghum bicolor* L., sorghum belongs to the family Gramineae and is believed to have originated in Africa. It is a carbohydrate-rich crop that plays a vital role in reducing hunger and ensuring food security, particularly among populations living in fragile agro-ecological zones. Sorghum serves as a staple food for millions of people in the semi-arid tropics and is often referred to as the “King of Millets” due to its importance and versatility. The crop is widely cultivated across many regions, including Africa, Asia, China, the United States, Mexico, and India, and is grown in more than 100 countries worldwide. While sorghum is primarily used as a staple food for human consumption in developing regions, it is also extensively utilized as a major feed crop for livestock in countries such as the United States, Brazil, and Australia. In recent years, increasing attention has been directed toward sorghum due to its nutritional value and functional properties, leading to a growing body of research focused on its role in human diets (Hossain et al., 2022; Stefoska-Needham, 2024; Khoddami et al., 2021; Ananda et al., 2020).

Despite its importance, significant post-harvest losses occur in cereal crops including

wheat, rice, maize, sorghum, and barley due to infestation by stored grain insects. Among these, *Tribolium castaneum*, *Rhyzopertha dominica*, and *Trogoderma granarium* are considered major pests responsible for considerable quantitative and qualitative losses. Studies have shown that these insects can cause up to 15% loss in stored grains under typical storage conditions (Muhammad et al., 2016). Such losses not only reduce the availability of food but also negatively impact grain quality and market value.

In view of the increasing challenges associated with post-harvest losses and the need for sustainable storage solutions, the development and identification of insect-resistant sorghum varieties have become highly important. The present study was therefore undertaken to evaluate the resistance of selected sorghum varieties against *Tribolium castaneum* under storage conditions. By assessing insect population dynamics and associated grain weight loss, the study aims to identify comparatively resistant varieties that can help reduce storage losses and contribute to improved grain storage management practices.

Materials and Methods: -

- **Insect Culture:** The test insect, *Tribolium castaneum* (Herbst), was obtained from naturally infested stored grains. The collected insects were cultured and maintained in the laboratory using 1 kg capacity plastic containers containing clean grains as a rearing medium. The culture was kept under ambient laboratory conditions to allow continuous breeding and development of the insect population. Healthy and active population from this stock culture were used for further experimental studies.
- **Sorghum Varieties:** Five sorghum (*Sorghum bicolor* L.) varieties were selected for the present investigation, namely CSH-16, CSH-17, CSH-6, CSH-15, and CSH-9. These varieties were procured from reliable agricultural sources and were used to evaluate their resistance against *T. castaneum* infestation under storage conditions.
- **Experimental Design and Bioassay Procedure:** The experiment was conducted under laboratory conditions using a completely randomized design. For each sorghum variety, 100 g of clean and un-infested grains were taken and placed in 500 ml plastic jars, which served as individual experimental units. Prior to the experiment, all grain samples were kept in a freezer for 24 hours to eliminate any pre-existing insect stages, ensuring uniform initial conditions. Each experimental unit was artificially infested with five third instar larvae of *T. castaneum*. The containers were then covered with muslin cloth to allow proper aeration while preventing insect escape. All experimental units were

maintained at room temperature under normal laboratory conditions throughout the study period.

- **Storage Duration and Observations:** The observations were recorded at different storage intervals of 3, 6, 9, and 12 months. At each interval, the level of infestation was assessed by recording the insect population developed in each container. Additionally, the extent of grain damage was evaluated by measuring the loss in grain weight. The percentage weight loss was calculated by comparing the initial and final weights of the grains.

Result and Discussion: -

The results presented in Table 1 and Table 2 clearly demonstrate that both the population buildup of *Tribolium castaneum* and the corresponding grain weight loss increased progressively with the advancement of storage duration across all sorghum varieties. This trend indicates that prolonged storage provides favourable conditions for the multiplication and establishment of the insect, leading to greater infestation and damage over time. As shown in Table 1, the insect population increased markedly from 3 to 12 months in all the tested varieties. At the initial storage period (3 months), the population ranged from 15.0 ± 1.2 insects \cdot 100 g⁻¹ in CSH-6 to 28.0 ± 2.1 insects \cdot 100 g⁻¹ in CSH-17, indicating relatively low infestation levels during early storage. However, as the storage period progressed, a rapid increase in insect population was observed. By 6 months, the population had increased approximately three to four times, and by 9 months, a substantial buildup was evident across all varieties.

At 12 months, the highest population was recorded in CSH-17 (420.0 ± 15.6 insects \cdot 100 g⁻¹), followed by CSH-9 (390.0 ± 14.2 insects \cdot 100 g⁻¹), indicating that these varieties were highly susceptible to *T. castaneum* infestation. In contrast, CSH-6 showed the lowest population (210.0 ± 9.8 insects \cdot 100 g⁻¹), followed by CSH-15 (240.0 ± 10.5 insects \cdot 100 g⁻¹), suggesting a comparatively higher level of resistance. CSH-16 exhibited intermediate behaviour, with a population of 310.0 ± 12.8 insects \cdot 100 g⁻¹ at 12 months.

The overall varietal effect further supports this trend, where CSH-17 (204.5 ± 8.4) and CSH-9 (189.0 ± 7.7) showed higher mean insect populations, while CSH-6 (101.3 ± 5.0) and CSH-15 (117.0 ± 5.5) maintained lower mean values. The observed differences among varieties may be attributed to inherent physical and biochemical characteristics of the grains, such as seed hardness, pericarp thickness, and the presence of secondary metabolites (e.g., tannins and phenolic compounds), which are known to influence insect feeding and

development.

Table 1: Population dynamics of *Tribolium castaneum* (insects·100 g⁻¹) in different sorghum varieties during storage

Variety	3 months	6 months	9 months	12 months	Variety effect
CSH-16	22.0 ± 1.6	85.0 ± 4.2	180.0 ± 7.5	310.0 ± 12.8	149.3 ± 6.5
CSH-17	28.0 ± 2.1	110.0 ± 5.8	260.0 ± 10.2	420.0 ± 15.6	204.5 ± 8.4
CSH-6	15.0 ± 1.2	60.0 ± 3.5	120.0 ± 5.6	210.0 ± 9.8	101.3 ± 5.0
CSH-15	18.0 ± 1.4	70.0 ± 3.9	140.0 ± 6.3	240.0 ± 10.5	117.0 ± 5.5
CSH-9	26.0 ± 1.9	100.0 ± 5.1	240.0 ± 9.5	390.0 ± 14.2	189.0 ± 7.7

The pattern of grain weight loss (Table 2) closely followed the trend observed in insect population dynamics, indicating a strong positive relationship between infestation level and grain damage. At 3 months, weight loss was minimal across all varieties, ranging from $1.8 \pm 0.1\%$ in CSH-6 to $3.2 \pm 0.3\%$ in CSH-17. However, with increasing storage duration, weight loss increased significantly in all varieties.

At 6 months, moderate losses were recorded, while at 9 months, the losses became more pronounced, particularly in susceptible varieties. By 12 months, maximum weight loss was observed in CSH-17 ($29.5 \pm 1.8\%$), followed by CSH-9 ($27.8 \pm 1.7\%$), indicating severe grain deterioration. In contrast, CSH-6 ($15.5 \pm 1.1\%$) and CSH-15 ($17.2 \pm 1.2\%$) exhibited comparatively lower weight loss, confirming their relative resistance. CSH-16 again showed intermediate values ($21.8 \pm 1.4\%$).

The varietal mean values further emphasize this trend, with CSH-17 (14.8 ± 1.0) and CSH-9 (13.8 ± 0.9) showing higher overall losses, while CSH-6 (7.8 ± 0.5) recorded the lowest. The reduced weight loss in resistant varieties may be due to lower feeding efficiency and reduced reproductive success of the insect on these grains.

Table 2: Percentage grain-weight loss in different sorghum varieties infested by *Tribolium castaneum* during storage

Variety	3 months	6 months	9 months	12 months	Variety effect
CSH-16	2.5 ± 0.2	6.8 ± 0.5	13.5 ± 0.9	21.8 ± 1.4	11.2 ± 0.7

CSH-17	3.2 ± 0.3	8.5 ± 0.6	17.8 ± 1.2	29.5 ± 1.8	14.8 ± 1.0
CSH-6	1.8 ± 0.1	4.5 ± 0.3	9.2 ± 0.6	15.5 ± 1.1	7.8 ± 0.5
CSH-15	2.0 ± 0.2	5.2 ± 0.4	10.8 ± 0.7	17.2 ± 1.2	8.8 ± 0.6
CSH-9	3.0 ± 0.2	7.8 ± 0.5	16.5 ± 1.1	27.8 ± 1.7	13.8 ± 0.9

A clear and consistent relationship was observed between insect population density and grain weight loss across all storage periods and varieties. Varieties that supported higher insect populations (CSH-17 and CSH-9) also exhibited greater weight loss, whereas those with lower insect populations (CSH-6 and CSH-15) showed reduced damage. This indicates that the extent of grain deterioration is directly dependent on the intensity of insect infestation.

Conclusion: -

The present investigation demonstrated that storage duration and varietal characteristics significantly influence the population of *Tribolium castaneum* and the extent of grain damage in sorghum. A consistent increase in insect population and weight loss was observed with prolonged storage across all varieties. Among the tested genotypes, CSH-6 and CSH-15 exhibited comparatively higher resistance, as evidenced by lower insect population and reduced grain weight loss, whereas CSH-17 and CSH-9 were found to be highly susceptible. CSH-16 showed moderate response under storage conditions. The results clearly establish a direct relationship between insect infestation and grain deterioration. Therefore, the use of resistant sorghum varieties can be considered an effective, eco-friendly, and economically viable approach for reducing post-harvest losses during storage. These findings may contribute to the development of improved storage strategies and support breeding programs aimed at enhancing insect resistance in sorghum.

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