# Susceptibility of Sorghum Cultivars to *Sitophilus oryzae* L. (Coleoptera: Curculionidae) During Storage

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**ABSTRACT**

*Sitophilus oryzae L. is a primary pest that causes damage to stored sorghum. The aim of this study was to evaluate the susceptibility of some sorghum cultivars to S. oryzae infestations and the damage resulted during storage period. The research was carried out at Plant Pest and Disease Laboratory, Department Agroecotechnology, Faculty of Agriculture, Malikussaleh University from February to June 2017. Nine cultivars of sorghum were screened for their susceptibility to S. oryzae attacks and the damage resulted. The Dobie sesceptibility indexwas used to classify the susceptibility of sorghum cultivars. Susceptibility experiment of several sorghum cultivars to S. oryzae was done by no choice assay. The results exhibited that sorghum cv. Suri 3, Suri 4, Kawali, and Numbu was categorized as moderate. Cv. Samurai 1 was included in moderate to susceptible, and cv. Super 1, Super 2, Samurai 2, and Pahat were categorized as susceptible to S. oryzae. The susceptibility of sorghum cultivars was determined by high number of F1 progeny, the high percentage of seed weight loss, damaged seeds, low median development time and low width of sorghum seeds.*

*Keywords: Sorghum cultivar, Susceptibility, Storage period, Sitophilus oryzae*

**ABSTRAK**

*Sitophilus oryzae* L. merupakan hama primer yang menyebabkan kerusakan sorgum di penyimpanan. Penelitian bertujuan mengevaluasi kerentanan dan kerusakan beberapa varietas sorgum terhadap infestasi *S. oryzae* selama di penyimpanan. Penelitian telah dilakukan di Laboratorium Hama dan Penyakit Tanaman, Program Studi Agroekoteknologi, Fakultas Pertanian, Universitas Malikussaleh dari bulan Februari–Juni 2017. Sembilan varietas sorgum dinvestigasi tingkat kerentanan dan kerusakan terhadap serangan *S. oryzae*. Indeks kerentanan Dobie digunakan untuk mengelompokkan derajat kerentanan varietas sorgum terhadap *S. oryzae*. Pengujian kerentanan beberapa varietas sorgum terhadap *S. oryzae* dilakukan tanpa uji pilihan. Hasil penelitian menunjukkan bahwa sorgum dari Varietas Suri 3, Suri 4, Kawali, dan Numbu tergolong moderat, sedangkan Varietas Samurai 1 tergolong moderat sampai rentan, dan Varietas Super 1, Super 2, Samurai 2, dan Pahat tergolong rentan terhadap *S. oryzae* selama penyimpanan sorgum. Kerentanan varietas sorgum ditentukan oleh jumlah F1 yang banyak, persentase kehilangan bobot biji dan persentase biji berlubang yang tinggi serta median waktu perkembangan dan lebar biji sorgum yang rendah.

Kata Kunci: Kultivar sorgum, Kerentanan, Periode penyimpanan, *Sitophilus oryzae*

## INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench.) is a major food cereal for millions of people in the world. It is considered as an alternative source of carbohydrates, and it has the potential as a rice supplementary food in Indonesia. Meanwhile, sorghum is mainly consumed in Africa and South Asia (Subagio & Aqil, 2014; Griebel et al., 2019). Sorghum has great potential to be cultivated in Indonesia because it is relatively drought tolerant, and it has a high nutrient content compared to rice. Sorghum storage is a part of postharvest activities, which is done after threshing and exfoliation (Subagio & Aqil, 2014). Generally, sorghum is stored as seeds or panicles. This is done to maintain the quantity and quality of sorghum from several factors that affect the commodity, such as the presence of stored-product pests and the increase in water content which triggers the appearance of fungi (Firmansyah et al., 2013). The main problem in developing sorghum is that sorghum is easily damaged during the storage period (Sirappa, 2003). The most common postharvest damage during the storage period is caused by the attack of stored-product pests. Stored-product pests that cause damage to stored sorghum are *Sitophilus spp., Corcyra cephalonica, Sitotroga cerealella, Plodia* *interpunctella, Rhyzoperta dominica* and *Ephis cautella* (Firmansyah et al., 2013; Tenrirawe et al., 2013).

*Sitophilus oryzae* L. is one of important pests attacking agricultural commodities such as cereals, and it is commonly found in Asian countries (Zunjare et al., 2016). This pest is classified as major and polyphagous pest, which causes intense damage to stored sorghum (Ladang et al., 2008; Bhanderi et al., 2015). Weight loss of sorghum during the storage period is caused by feeding activities of both larvae and adults (Prasad et al., 2015). The adults and larvae attack from the inside of sorghum seeds, causing economic losses (quantity and quality damage) to sorghum during the storage period (Bhanderi et al., 2014). The infestation of these pests on sorghum also deteriorates seed germination and contaminates the seeds with exuvia, excretion accumulation, and fungal contamination during storage. Other qualitative losses are related to changes in the biochemical components of cereals such as the decrease in carbohydrate, starch, and protein content (Danjumma et al., 2009). Sorghum damage during storage could lower the value of sorghum (Reddy et al., 2002).

Damage to sorghum during the storage period caused by *S. oryzae* can be reduced by storing resistant sorghum. Bamaiyi et al. (2007) reported that there was a variability of each sorghum cultivar to the population and median development time of *S. oryzae*, susceptibility index, and percentage of damage and loss of yield weight. The results of the study by Pradeep et al. (2015) showed that there were 5 out of 20 sorghum cultivars that had a high level of resistance to *S. oryzae* with lower damage to sorghum seeds for 120 days of storage. Variations in sorghum damage caused by larvae and adults of *S. oryzae* are related to the differences in the characteristics of sorghum cultivars, thus affecting the susceptibility of sorghum (Pradeep & Jagginavar, 2015). To lower the damage during storage period, the use of resistant sorghum cultivars is highly recommended. In Indonesia, sorghum is still considered as unpopular food. However, this plant is promising for the economic growth and also prospective for grain cultivation due to its drought-resistance. Because of these reasons, it is necessary to conduct further evaluation, especially on its susceptibility to *S. oryzae* attack. Information on sorghum susceptibility is needed as a guideline to sorghum breeding program to support the development of sorghum. Hence, this study aimed to evaluate the susceptibility and damage of several sorghum cultivars to *S. oryzae* infestations during the storage period.

## MATERIALS AND METHODS

### Mass-rearing and infestation of *S. oryzae*

Insects were prepared following the method of Hendrival & Meutia (2016). A total of 40 adults were reared on 250 g of red rice and stored in maintenance jars for 4 weeks. After 4 weeks, the insect were removed from the jars. Then, the insects were re-incubated to red rice until the progeny appeared. Separation was carried out continuously every day until certain number of adults was obtained. A total of 10 *S. oryzae* adult pairs from stock rearing (aged 7 days) were placed in glass vials (diameter of 15 cm and height of 12 cm). Each glass vials contained sorghum (200 g) of various cultivars and they were maintained in laboratory at a temperature of 27 - 30 $^{o}$C and RH of 70 - 75 %.

### Characteristic of various sorghum cultivars

Nine sorghum cultivars were screened for their susceptibilities to *S. oryzae*. Cultivar Super 1, Super 2, Suri 3, Suri 4, Kawali, and Numbu were obtained from Cereals Research Institute, Maros, South Sulawesi. Cv. Samurai 1, Samurai 2, and Pahat were obtained from the National Nuclear Energy Agency of Indonesia (BATAN). The seed dimension (length, width, and diameter) was measured from 20 seeds randomly observed. The seed length was measured between the two ends of whole seeds, while the seed width was measured between the back and abdomen of whole seeds. The digital calipers (mm) were used to measure the seed dimension (Table 1). The moisture content of sorghum seeds ranged from 10.55 - 10.88 %.

### Determination of sorghum susceptibility

The susceptibility of sorghum was determined by Dobie susceptibility index (Dobie, 1974) which calculation is based on the appearance of F1 progeny and median development time of *S. oryzae*. The adults of *S. oryzae* were allowed to infest each of three glass vials containing 200 g sorghum seeds for ten days. After ten days, oviposition period of *S. oryzae* was discharged from each glass vials. The insects were counted 35 days post-infestation when the F1 progenies started emerging (the mean developmental period is 35 days). The emergent adults were counted daily and recorded. Sampling for adult emergence continued up to the 50th day when most F1 progenies had emerged (Bamaiyi et al., 2007). The median developmental period (days) is estimated as the time from the middle of the oviposition period to the emergence of 50 % of the F1 progeny. Median development time was observed daily since oviposition period (10 days after infestation) until 50 % progeny appeared. The susceptibility level of sorghum can be categorized as resistance (susceptibility index range of 0 - 3), moderate (range of 4 - 7), susceptible (range of 8 - 10), and very susceptible (> 11). The susceptibility index was calculated using the following formula.

$$\text{Susceptibility index} = 100 \times \frac{\left(\text{Log}_e \times \text{number of F1 progeny of } S.\ oryzae\right)}{\text{Median development time of } S.\ oryzae}$$

### Determination of Damaged Seeds

The damaged seeds were measured by calculating the percentage of seed weight loss and damaged seeds in samples of 100 seeds which had been stored for 60 days. The damaged seeds were expressed as a proportion of the total number of seed samples from each glass vials. Sorghum seeds which were used in the research needed to be stirred so that the damaged and undamaged seeds mixed perfectly. The seed weight loss and damaged seeds were calculated using the following formula (Gwinner et al., 1996).

$$\text{Weight loss} = \frac{(W_u \times N_d) - (W_d \times N_u)}{W_u \times (N_d + N_u)} \times 100\%$$

$$\text{Damaged seed} = \frac{N_d}{N} \times 100\%$$

Where:

Wu = weight of undamaged seeds
Nu = number of undamaged seeds
Wd = weight of damaged seeds
Nd = number of damaged seeds
N = number of samples

### Data Analysis

Data collected were analyzed using Analysis of Variance (ANOVA) with the tool of Statistical Analysis System (SAS) software. Pearson's coefficient correlation was obtained using the same statistical analysis.

## RESULTS AND DISCUSSION

### The number of F1 Progeny

Sorghum cultivars significantly affected the number of F1 progeny in 200 g of sorghum seeds (F = 15.17**; df = 8; P <0.0001). Sorghum cv. Samurai 2, Pahat, Super 1, and Super 2 significantly had a higher number of F1 progeny compared to cv. Samurai 1, Suri 3, Suri4, Kawali, and Numbu. The highest number of F1 progeny was found in cv. Samurai 2 (541 adults), however, not significantly

**Table 1.** Seed Dimension of Several Sorghum Cultivars

| Sorghum Cultivars | Seed dimension | | |
|---|---|---|---|
| | Length (mm) | Width (mm) | Diameter (mm) |
| Samurai 1 | 4.08 | 3.94 | 2.82 |
| Samurai 2 | 3.98 | 3.90 | 2.84 |
| Pahat | 3.97 | 3.98 | 2.89 |
| Super 1 | 4.14 | 3.90 | 2.78 |
| Super 2 | 4.85 | 3.91 | 2.68 |
| Suri 3 | 4.95 | 4.08 | 2.77 |
| Suri 4 | 4.20 | 3.92 | 2.19 |
| Kawali | 4.18 | 4.14 | 3.00 |
| Numbu | 4.18 | 4.07 | 2.81 |

different from those found in cv. Pahat, Super 1, and Super 2. The lowest number of F1 progeny was found in cv. Kawali (153.67 adults) but was also not significantly different from those found in cv. Suri 3, Suri 4, and Numbu. Cv. Samurai 1 reached up to 384.33 adults. Sorghum seeds cv. Samurai 2, Pahat, Super 1, and Super 2 were preferred by *S. oryzae* compared to sorghum seeds cv. Samurai 1, Suri 3, Suri 4, Numbu, and Kawali (Table 2). The preference level of *S. oryzae* on sorghum was shown on the number of F1 progeny appeared. This preference level of *S. oryzae* on sorghum cultivars can also be described, consecutively, as follows Samurai 2 = Pahat = Super 1 = Super 2 > Samurai 1 > Numbu = Suri 3 = Suri 4 = Kawali.

The difference in the number of adults might be determined by nutrient content and physical properties of each sorghum cultivar. These differences indicated that variability existed between the sorghum cultivars evaluated, allowing the identification of resistant cultivars. The difference in sorghum cultivars determines the appearance of F1 progeny due to differences in physical characteristics between them (Bamaiyi et al., 2007). These physical characteristics (pericarp texture, skin hardness, temperature and moisture content of sorghum seeds) are a source of resistance against *S. oryzae* (Gerema et al., 2017). Khan & Halder (2012) also revealed that the type, skin hardness and size of rice influenced the oviposition, reproduction, and development of *S. oryzae*. This result is similar to the findings of Prasad et al. (2015) reporting that the size of sorghum seeds determined the size and number of *S. oryzae* progeny. The adults of this pest preferred sorghum with a bigger size, which is the best for laying their eggs compared to small sorghum ones. Sorghum cv. Samurai 1, Suri 3, Suri 4, Kawali, and Numbu exposed the characteristics preferred by *S. oryzae*.

### Median Development Time

The results described in Table 2 show that different cultivars of sorghum significantly affected the median development time of *S. oryzae* during storage period (F = 13,47**; df = 8; P< 0,0001). The shortest median time development was shown by *S. oryzae* found in cv. Samurai 2 and Pahat (32.33 days), however, it was not significantly different from the median time development of the insects found in cv. Super 1 and Super 2. The longest median development time was observed in cv. Kawali (36.67 days) though there was no significant difference compared to those found in cv. Suri 3, Numbu, and Suri 4. Manwhile, the median development time observed in cv. Samurai 1 reached up to 34 days (Table 2).

The median development time from eggs to adults ranged from 32.33 to 36.67 days. This finding was slightly different from the research done by Bamaiyi et al. (2007) which found out that the median development time ranged from 32.97–42.97 days. The median time for development of *S. oryzae* in sorghum also has similarities to the development time of S. zeamais in the same stored product (Chuck-Hernández et al., 2013; Goftishu & Belete, 2014). Short median development time causes sorghum to be more susceptible to *S. oryzae*. According to Gerema et al. (2017), susceptible sor-

**Table 2.** Number of $F_1$ Progeny, Median Development Time, and Susceptibility Index of Sorghum Cultivars

| Cultivars | Number of F1 progeny | Median development time (days) | Susceptibility index | Susceptibility category |
|---|---|---|---|---|
| Samurai 1 | 384.33 b | 34 b | 7.60 b | Moderate-susceptible |
| Samurai 2 | 541 a | 32.33 c | 8.45 a | Susceptible |
| Pahat | 508.67 ab | 32.33 c | 8.37 a | Susceptible |
| Super 1 | 505 ab | 32.67 bc | 8.23 ab | Susceptible |
| Super 2 | 515.33 ab | 33.67 bc | 8.03 ab | Susceptible |
| Suri 3 | 192.33 c | 36.33 a | 6.25 c | Moderate |
| Suri 4 | 165.33 c | 35.67 a | 6.20 c | Moderate |
| Kawali | 153.67 c | 36.67 a | 5.94 c | Moderate |
| Numbu | 236.67 c | 36 a | 6.59 c | Moderate |

Remarks: Means in the same column followed by the same letters do not differ significantly (P = 0.05) as determined by DMRT at 5%.

ghum resulted from shorter median development of S. *oryzae* infesting it, and Chuck-Hernández et al. (2013) also revealed the similar results on the sorghum susceptibility to infestation of S. zeamais. Interestingly, the median development time of S. *oryzae* also influenced the number of eggs laid by S. *oryzae*. The short median development time causes a greater number of eggs laid and more adults to appear (Prasad et al., 2015). From these results, it can be concluded that shorter median development attributed to a greater number of F1 progeny, while the insects with longer development time produced a lower number of F1 progeny (Bamaiyi et al., 2007).

## Susceptibility Index of Sorghum Cultivars

Table 2 showed that there were significant effects of sorghum cultivars of sorghum on the susceptibility index ($F = 20.22^{**}$; df = 8; $P < 0.0001$). The highest susceptibility index was demonstrated by cv. Samurai 2 and Pahat, reaching 8.45 and 8.37 though it was not significantly different from the susceptibility index of cv. Super 1 and Super 2. Meanwhile, the lowest index was observed in varieties Kawali, Suri 4, Suri 3 and Numbu. According to these findings, cv. Samurai 2, Pahat, Super 1, and Super 2 were categorized as susceptible varieties, cv. Samurai 1 was moderate-susceptible, and cv. Kawali, Suri 4 and Suri 3 were moderate to the attack of S. *oryzae*. The susceptibility of sorghum seeds was also influenced by the number of F1 progeny ($r = 0.988^{**}$; $P < 0.01$), width of sorghum seeds ($r = -0.726^{*}$; $P < 0.05$), and median development time ($r = -0,978^{**}$; $P < 0.01$) (Table 4). This result was in accordance with that of Bamaiyi et al. (2007) and Goftishu & Belete (2014) reporting that the susceptibility of sorghum cultivars was influenced by the number of F1 progeny and median development times of S. *oryzae* and S. zeamais. A large number of F1 progeny and short median development time led to high susceptibility index, causing the sorghum to be more susceptible to both S. *oryzae* and S. zeamais. The results of this study showed that susceptibility of sorghum to S. *oryzae*

**Table 3.** Percentage of Weight Loss and Damaged Seeds of Different Sorghum Cultivars

| Cultivars | Percentage of weight loss | Percentage of damaged seeds |
|---|---|---|
| Samurai 1 | 3.24 de | 12 abc |
| Samurai 2 | 8.82 a | 19.67 a |
| Pahat | 6.37 abc | 16.33 ab |
| Super 1 | 5.92 abcd | 15.67 ab |
| Super 2 | 6,57 ab | 18.67 a |
| Suri 3 | 3.65 bcde | 9.33 bc |
| Suri 4 | 2.95 e | 8 c |
| Kawali | 3.62 bcde | 8.76 c |
| Numbu | 3.80 cde | 9.33 bc |

Remarks: Means in the same column followed by the same letters do not differ significantly (P = 0.05) as determined by DMRT at 5%.

**Table 4.** Correlation Coefficient Between Seed Length, Seed Width, Seed Diameter, Number of $F_1$ Progeny, Median Development Time, Percentage of Weight Loss, Percentage of Damaged Seeds and Susceptibility Index of Sorghum Cultivars

| Characteristics | Seed length | Seed width | Seed diameter | Number of $F_1$ progeny | Median development time | Percentage of weight loss | Percentage of damaged seeds | Susceptibility Index |
|---|---|---|---|---|---|---|---|---|
| Seed length | 1 | | | | | | | |
| Seed width | 0.190 | 1 | | | | | | |
| Seed diameter | -0.153 | 0.440 | 1 | | | | | |
| Number of $F_1$ progeny | -0.208 | -0.712 | 0.258 | 1 | | | | |
| Median development time | 0.381 | 0.767** | -0.158 | -0.944** | 1 | | | |
| Percentage of weight loss | -0.161 | -0.518 | 0.282 | 0.851** | -0.694* | 1 | | |
| Percentage of damaged seeds | -0.087 | -0.679* | 0.228 | 0.967** | -0.848** | 0.933** | 1 | |
| Susceptibility Index | -0.283 | -0.726* | 0.245 | 0.988** | -0.978** | 0.780** | 0.921** | 1 |

Remarks: ** Significant at 1% level, * significant at 5% level

was also influenced by physical characteristic of sorghum, which is the seed width. The physical characteristic of sorghum seeds is an indicator of its susceptibility to *S. oryzae*. According to Siwale et al. (2009), the resistance of seeds to insect is influenced by the physical characteristic. Physical characteristics of cereals are attributed to their sensitivity to the attack of S. zeamais (Akpodiete et al., 2015; Throne & Eubanks, 2015; Rahardjo et al., 2017).

### Determination of Sorghum Losses

There was significant difference in sorghum losses between cultivars (Table 3). Each cultivar demonstrated significantly different losses compared to others such as weight loss (F = 3.73**; df = 8; P <0.0097) and damaged seeds (F = 3.55*; df = 8; P <0.0122). Sorghum damage during storage occurred mostly in cv. Samurai 2, Super 2, Pahat, and Super 1, while the least damage occurred in cv. Kawali, Suri 4, and Numbu. The damage is related to the feeding activities of larvae and adults by causing symptoms such as cracked and perforated seeds as well as the production of frass. The frass production disables sorghum seeds to be processed into livestock feed, and also, it is inappropriate for human consumption. Sorghum damage leads to their susceptibility. Sorghum with high damage is immensely susceptible to *S. oryzae*. The results of the correlation analysis showed that there was a significant positive correlation between the percentage of weight loss (r = 0.780**; P <0.01) and the percentage of damaged seeds (r = 0.921**; P <0.01) and the susceptibility of sorghum. Correlation between these characters indicated that heavy damage enables sorghum to be highly susceptible. Sorghum damage during storage period was also influenced by the number of F1, which affected the percentage of weight loss (r = 0.851 **; P <0.01) and the percentage of damaged sorghum (r = 0.967 **; P <0.01) (Table 4). It is in accordance with the results of Gerema et al. (2017). They reported that the number of F1 progeny of *S. oryzae* influenced the damage of sorghum and caused weight loss, which was positively correlated with the susceptibility index. Sorghum cv. Suri 3, Suri 4, Kawali, and Numbu were moderately susceptible to *S. oryzae*. These cultivars could be recommended as they exposed an important role in minimizing sorghum losses during storage period in the tropics.

## CONCLUSIONS

These nine sorghum cultivars can be categorized from moderate to susceptible to infestations of *S. oryzae*. Cv. Suri 3, Suri 4, Kawali, and Numbu were categorized as moderate, while cv. Samurai 1 was categorized as moderate to susceptible. Meanwhile, cv. Super 1, Super 2, Samurai 2, and Pahat were susceptible. The susceptible sorghum seeds are not recommended to be stored for long periods as it deteriorates further due to the attack of *S. oryzae*.

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