Integrated Protection of Stored Products
IOBC-WPRS Bulletin Vol. 148, 2020
pp. 377-384

Does the choice of a suitable sorghum hybrid help control the maize weevil in the tropic region?

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Abstract: Sorghum is the fifth most important cereal grown in Brazil, with a total production of 2,177 thousand tons, in the 2018/19 crop. Widely used in animal feed, sorghum is stored for a few months and damaged, especially by maize weevil, *Sitophilus zeamais*. The lack of data about the susceptibility of modern hybrids of sorghum to maize weevil may underestimate the potential loss, especially in the tropics.

Therefore, the objective of this study was to identify sources of resistance to *S. zeamais* in sorghum hybrids during storage. The experiments were carried out using glass jars (1.7 l), with about 1.5 kg of 35 sorghum hybrids grains, characterized by water content and specific mass. The jars were infested with 70 adult insects and stored under ambient conditions (January-April). After 100 days of storage, number of live insects, water content and specific mass were assessed. Weight loss was estimated by data on specific mass corrected by water content. The experimental design was completely randomized with three replicates for each hybrid and the data underwent analysis of variance followed by the Waller-Duncan test ($p < 0.05$), in addition to correlation and cluster analysis.

There was a significant difference in the number of adult *S. zeamais* among the hybrids ($F_{34,96} = 1.63$, $P < 0.0482$), with hybrids CMSXS3002, 50A50, CMSXS3000 and 1527039, with a smaller number of live insects after storage. The hybrids with the highest number of live insects were AGN1806, XB6018, BRG37115 and BRS373. Significant and positive correlation was found between weight loss and number of live insects. Some sorghum hybrids demonstrate tolerance to the development of *S. zeamais*; however, in the more susceptible ones, losses can occur over 11.6% in the period of 100 days of storage.

Key words: *Sitophilus zeamais*, varietal resistance, tropical regions, *Sorghum bicolor*, grain storage

Introduction

Sorghum is one of the most important cereals grown in Brazil; in the 2018/2019 harvest, it is expected to reach a planted area of 732.3 thousand hectares, average productivity of 2,973 kg/ha and total production of 2,177 tons (Conab, 2019). Much of the area is concentrated in the states of Goiás and Minas Gerais, where sorghum is grown at intervals between soybean and corn. This crop has been an excellent option for a second crop, referred to as "safrinha" cultivation, especially after the ideal window for planting corn, which can still provide good levels of productivity because of its rusticity (Almeida Filho et al., 2014). Much of the national production is destined to the production of animal feed for pigs, poultry, and pets, because it is a source of energy in diets.

As this cereal is generally produced in the second crop, it is harvested between June and August in the midwest and southeast (Conab, 2019). It is a dry season of the year, with low relative humidity, which favors drying of grains in the plant; thereofore, at harvesting, water content levels are similar to those that are ideal for storage, around 13% (Brasil, 1984; Almeida Filho et al., 2014; Pimentel, 2015). However, despite a significant yield, good health quality of the grains at harvest and high stability against abiotic factors, during storage, high losses can occur and significantly affect the viability of production. Losses in the storage period, usually over six months, can exceed 20% as the result of insect attacks alone (Chuck-Hernández et al., 2013; Mendes et al., 2014; Goftishu and Belete, 2014). The main insect pest species associated with storage loss in tropical regions is the maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) (Lorini, 2002; Santos, 2008; Pimentel, 2015).

The main strategy of controlling this insect pest during storage in Brazil is the use of insecticides, fumigants or residuals, which are applied directly to grains. However, for stored sorghum, few registered insecticides are currently available and climatic conditions, especially high temperatures, contribute to the development of insect pests of stored products (Brasil, 2003; Mendes et al., 2014; Pimentel, 2015). Given the few options of management strategies and the importance and magnitude of damage at postharvest, varietal resistance may be a control tactic to be included in the Integrated Pest Management (IPM) (Throne et al., 2000). The resistance of sorghum cultivars to insect pests of stored products may be an alternative and environmentally friendly form of passive control, which may suppress pest insect development and maintain the quality of stored grains, reducing insect damage, and favoring the profitability of farmers (Throne et al., 2000; Garcia-Lara et al., 2004).

Studies to identify sources of resistance to *S. zeamais* in Brazil, especially for sorghum, are limited and rare (Torres et al., 1996). The screening of sorghum hybrids to identify genetic resistance to maize weevil is important because it can be used as a donor source in breeding programs or used directly by farmers (Chuck-Hernández et al., 2013). The objective of this study was to identify sources of resistance to *S. zeamais* in modern sorghum hybrids during storage and estimate the grain loss of different hybrids caused by *S. zeamais*.

Material and methods

The bioassays to evaluate the susceptibility of commercial sorghum hybrids to *S. zeamais* infestation were performed at Embrapa's laboratory, in Sete Lagoas-MG, from October 2016 to February 2017.

Insect rearing

The insects of *S. zeamais* were reared in 1.5 l glass jars, kept under laboratory conditions of temperature (25 °C) and humidity (72%). As food substrate, whole sorghum grains were used. The grains had water content of 13% on a wet basis (wb); they were fumigated with phosphine (PH_3) and kept under refrigeration (-18 °C) to prevent reinfestation.

Sorghum hybrids

The sorghum grains were harvested on Embrapa's experimental fields, and the grains were traced, air-cleaned and sieved, in the laboratory, and fumigated using phosphine, to eliminate possible cross infestation by insects from the production field. Thirty-five hybrids were used in susceptibility bioassays: 1236020, 1527039, 1G100, 50A50, AG1080, AGN1803, AGN1806,

AGN1809, AL PRECIOSO, BRG21463, BRG23004, BRG35365, BRG37115, BRG37555, BRS330, BRS373, CH9102, CH9104, CMSXS3000, CMSXS3002, HL-02, HL-04, HL-05, IA7021, NSX2015, NSX2017, S15J003E, S16J002D, S16J003D, SP2R01, SP2R02, XB6015, XB6018, XB6053 and XB6080. The hybrids were planted and harvested in three separate replications, in a total of 105 samples of about four kilograms each.

Bioassays procedure

After the fumigation period, the grains of each experimental plot were homogenized and reduced using a grain splitter to remove a working sample of approximately 1.5 kg, which was initially characterized for water content and volumetric weight. After initial characterization, 1.5 kg of grains from each hybrid were placed in glass jars (1.7 l). The jars were infested with 70 unsexed adult insects, with age varying from one to five days of emergence and stored under ambient conditions. During the conduction of the bioassays, the average temperature was 24.1 °C (with a maximum of 36.1 °C and a minimum of 15.4 °C) and the average relative humidity of the period was 72.9% (with a maximum of 97.0% and minimum 19.0%). After 70 days of storage, the flasks were evaluated by counting the total number of live and dead insects.

Volumetric weight was determined based on the sample initially collected (1.5 kg) using a kit for determining the volumetric weight (density) of grains (Gehaka®) with capacity of one liter of grains. After 70 days of storage, the volumetric weight after the infestation period was evaluated. The initial and final volumetric weight analyses were performed in three repetitions, and the results were expressed in kg/m^3, according to the recommendations of the Seed Analysis Rules (Brasil, 2009). Grain water content was also initially determined after homogenization and reduction of samples from each plot and after the end of the storage period (70 days), following the recommendations of the Seed Analysis Rules (Brasil, 2009). After measuring the volumetric weight and water content of the grains, the percentage of apparent bulk loss was estimated considering the relationship between initial bulk density before insect infestation (time zero) and at the end of 70 days of storage for the thirty-five hybrids.

Statistical analyses

The experiment used a completely randomized design with three replications for the 35 sorghum hybrids. Data on the total number of live insects and weight loss (%) on each sorghum hybrid were submitted to analysis of variance, and the means were compared by the Waller-Duncan test ($p < 0.05$), in addition to correlation analysis. A cluster analysis was performed using the Hierarquical Cluster Analysis – UPGMA method, based on the Euclidean distance, to group hybrids by their level of resistance.

Results and discussion

***Susceptibility of sorghum hybrids to* S. zeamais**

Figure 1 shows the number of live insects in the 35 sorghum hybrids. There was significant variation in the final number of live adult insects among the 35 sorghum hybrids evaluated ($F_{34;96} = 1.63$; $P < 0.0482$). The number of live insects after 70 days of storage indicated that six hybrids (CMSXS3002, 50A50, CMSXS3000, 1527039, AG1080 and BRS 330) were moderately resistant to *S. zemais* (Figures 1 and 2). The hybrids with the highest number of live insects were BRG37555, BRS373, BRG37115, XB6018 and AGN1806, ranging from 482.7, 413.8, 408.5, 395.7 and 389.3 live adult insects, respectively (Figures 1 and 2).

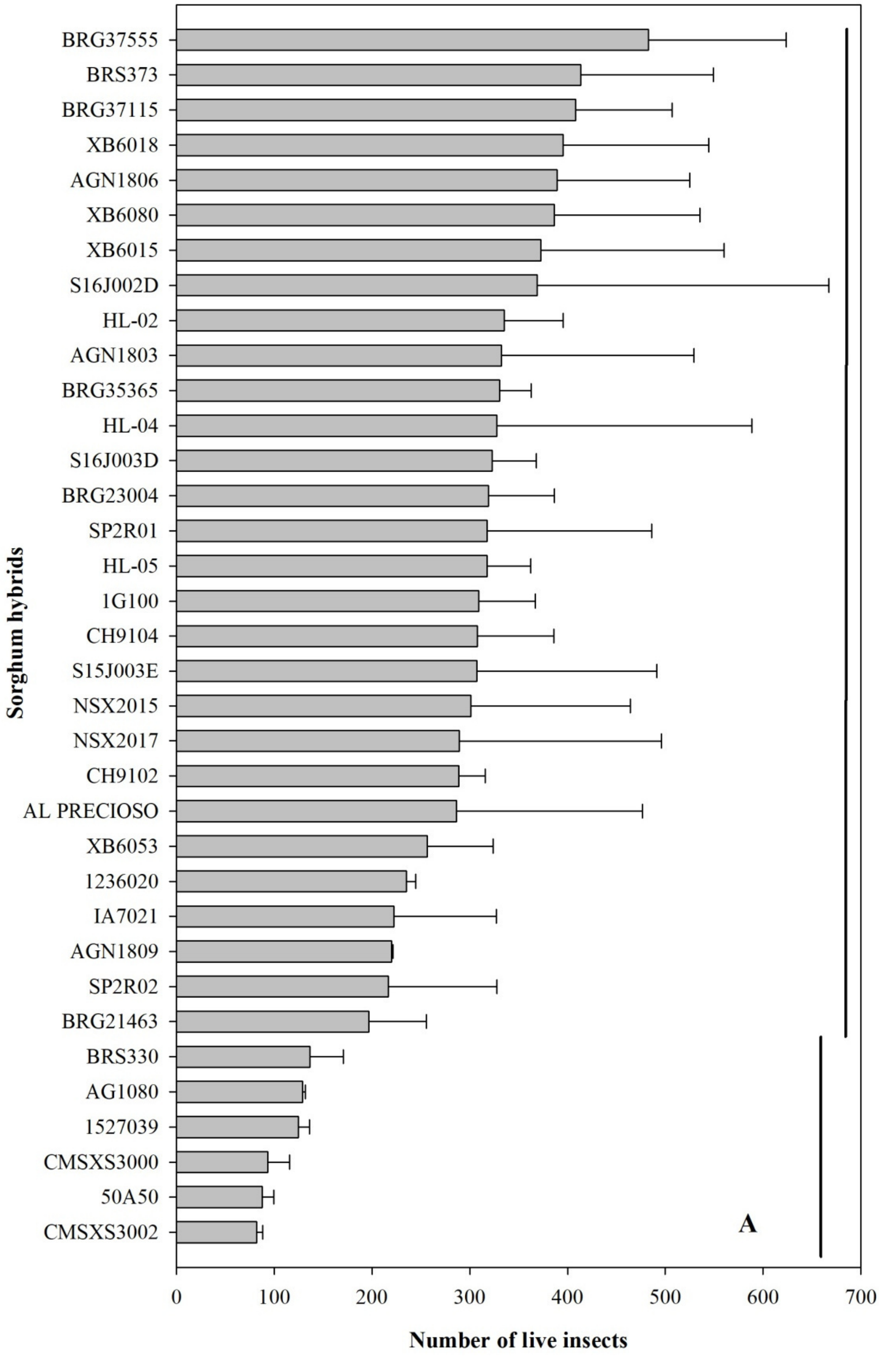

Figure 1. Number of live insects (± SEM) of *Sitophilus zeamais* in 35 sorghum hybrids. Histogram bars (± SEM) indicate the mean of three independent replicates and the vertical lines connect undistinguishable hybrids based on the Waller-Duncan test (P < 0.05). Sete Lagoas, Minas Gerais, Brazil.

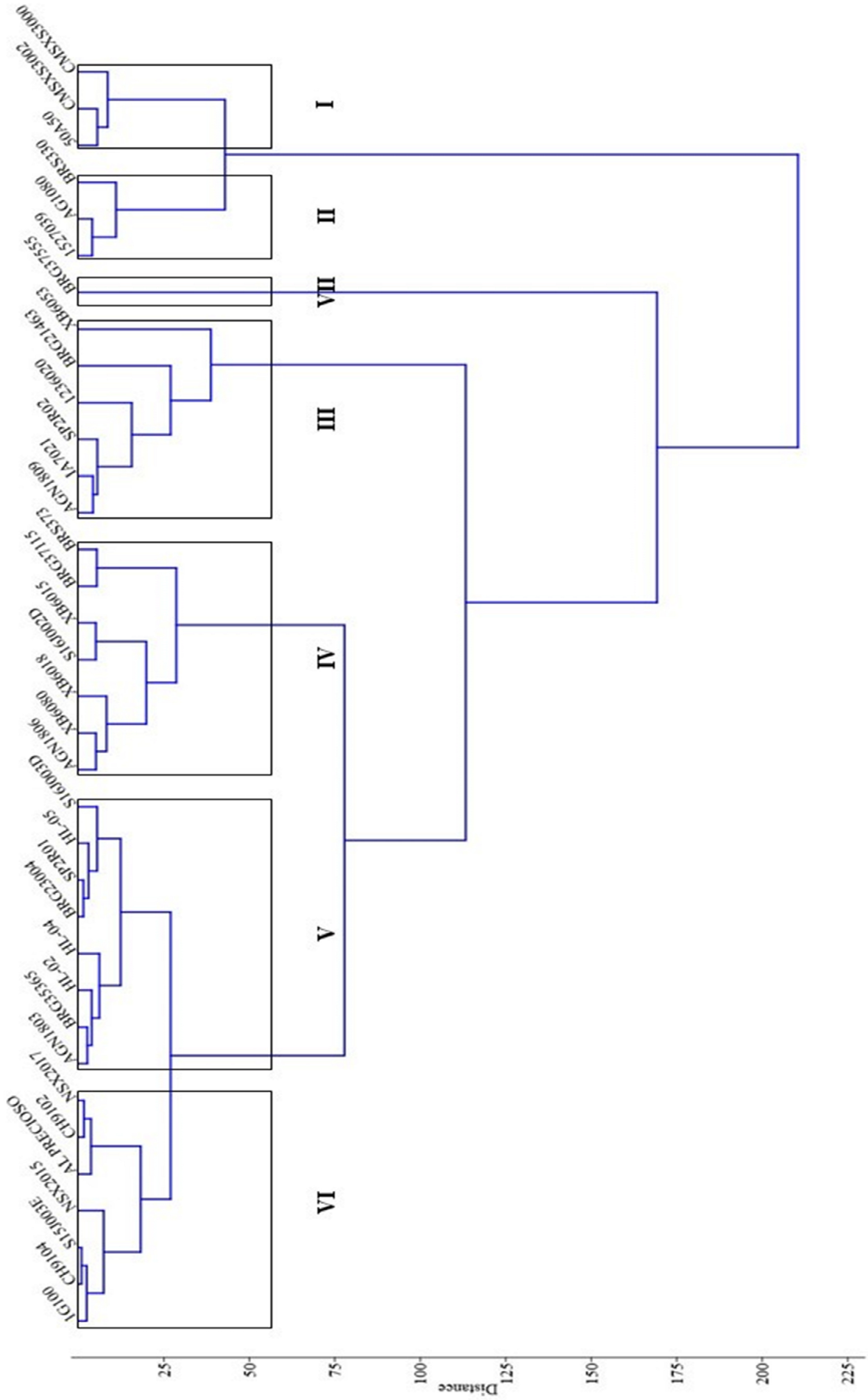

Figure 2. Dendrogram resulting from the multivariate grouping analyses using the UPGMA method, based on the Euclidean distance from the number of live insects and weight loss on 35 sorghum hybrids. Sete Lagoas, Minas Gerais, Brazil.

The hybrids were grouped by level of resistance, based on the UPGMA analysis (Figure 2). Groups I and II showed moderate resistance, the hybrid BRG37555 (group VII) was the most susceptible, and groups IV, V and VI presented high susceptibility to *S. zemais*. This was supported by the number of live insects and weight loss, as shown in Figures 1 and 3.

The initial ($F_{34;96}$ = 0.94; P < 0.5737) and final ($F_{34;96}$ = 0.95; P < 0.5569) water content did not vary significantly among the sorghum grains of the 35 hybrids, with an initial mean of 13.68% with coefficient of variation of 4.70%, and mean water content value at the end of 70 days of storage of 14.44% with coefficient of variation of 4.01%. The variation of the non-significant water content can be explained by the hygroscopic balance of the grains with the ambient temperature and relative humidity conditions during the crop on the field and the 70 days of storage.

Considering the storage of sorghum grains for more than 70 days under the tropic conditions of temperature and relative humidity (average temperature up 24 °C and average relative humidity up 70%), the hybrids CMSXS3002, 50A50, CMSXS3000, 1527039, AG1080 and BRS 330 were found to have moderate resistant to losses caused by *S. zeamais* for grain storage in a similar period and climate conditions.

***Weight loss by* S. zeamais**

Figure 3 shows the percentage of weight loss in the 35 sorghum hybrids. There was also significant variation between hybrids for weight loss during storage ($F_{34;96}$ = 1.74; P < 0.0297). It was found that weight loss increased with increasing number of live insects, and there was a positive and significant correlation (r = 0.3437; P < 0.0006). Our results with positive and significant correlation between number of live insects and weight loss were also reported in the work of Torres et al. (1996), who found significant positive correlations between these two parameters.

The hybrids that showed the highest percentage of loss after 70 days of storage were XB6053, AGN1806, BRS330, BRG37555 and S16J003D, ranging from 11.6, 10.3, 10.2, 8.7 and 8.3 percent of weight loss, respectively. Goftishu and Belete (2014), in experiments with 21 African varieties of sorghum, found a positive and significant correlation between weight loss and F1 progeny of *S. zeamais*, with an average weight loss of 12.4% in the Fendisha-5 variety. Chuck-Hernández et al. (2013) found a similar behavior in a study with 12 different cultivars of sorghum, with a positive and significant correlation between number of insects emerged after 30 days and percentage of grain weight loss. The same authors found maximum losses of up to 10.5% after 45 days of grain infestation with *S. zeamais*.

The results found in this study suggest that CMSXS3002, 50A50, CMSXS3000, 1527039, AG1080 and BRS 330 hybrids are promising for use in breeding programs aimed at resistance to maize weevil, or they can be used directly by sorghum farmers in Brazil. Moreover, these results indicate that, in tropical regions, *S. zeamais* has a potential for weight loss until 11.6% on sorghum grains for a short storage period (100 days). Regarding a more applied perspective, it should be noted that some resistant hybrids were shown to be ready to use by farmers. In these cases, association with other management strategies – that are based on the chemical, physical and sanitation control – is recommended.

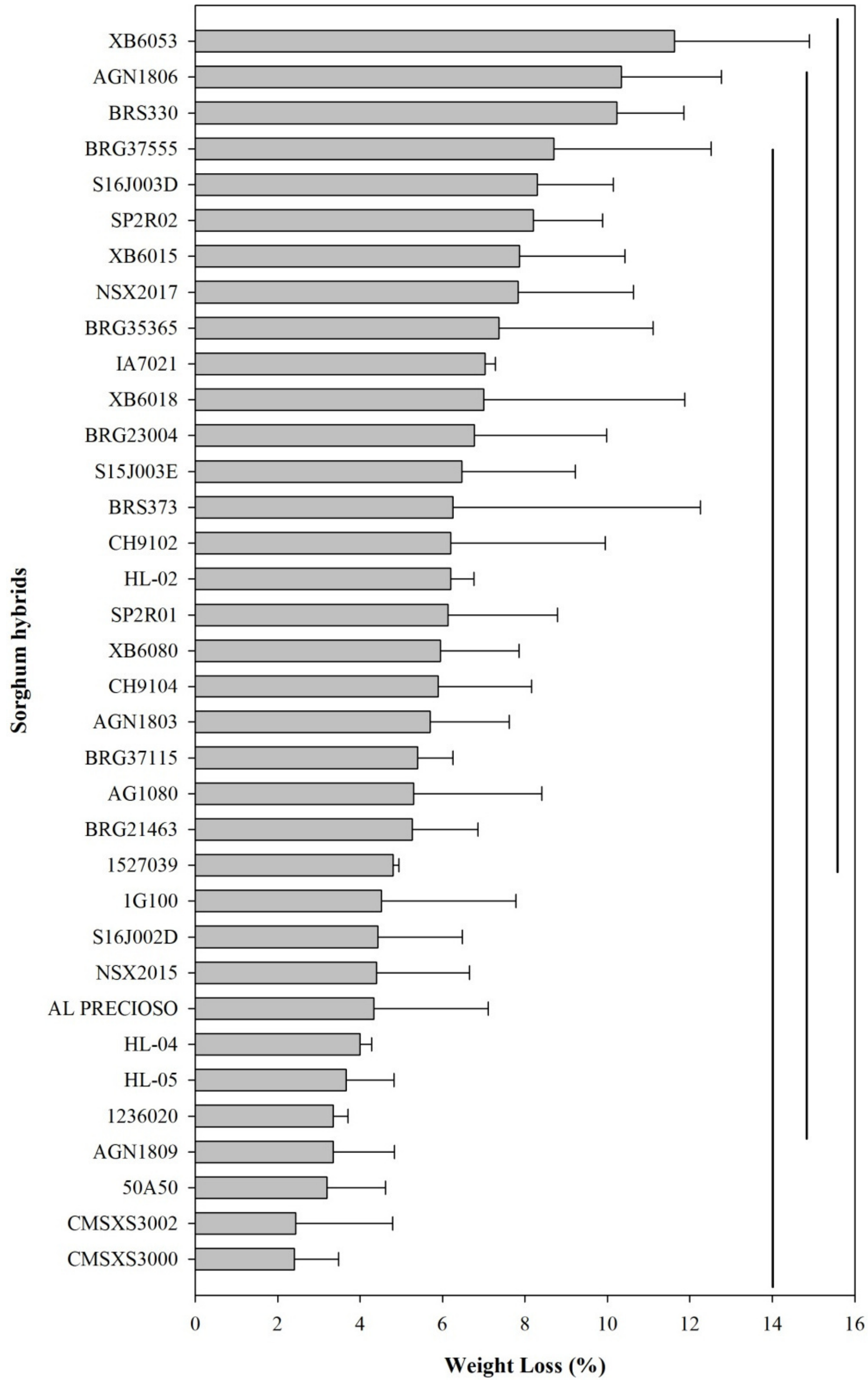

Figure 3. Weight loss (± SEM) caused by *Sitophilus zeamais* in 35 sorghum hybrids. Histogram bars (± SEM) indicate the mean of three independent replicates and the vertical lines connect undistinguishable hybrids based on the Waller-Duncan test ($P < 0.05$). Sete Lagoas, Minas Gerais, Brazil.

Acknowledgements

We are thankful to Embrapa for supporting this study (SEG number 22.15.05.002.00.00) and we would like to thank Ismael Moreira Maciel for his technical assistance on the assays and rearing of *S. zeamais*.

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