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Controlling weevils in maize by means of physical disturbance

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Abstract

Maize weevils (*Sitophilus zeamais*) can cause large losses in maize stored by smallholder farmers. Physical disturbance (tumbling) has been shown to be effective in controlling bean weevils in common beans, but we found no reports describing this approach for maize weevils. The objective was to determine effectiveness of storage container physical disturbance for maize weevil control. We conducted a laboratory experiment with two treatments: control (undisturbed) containers and disturbed containers, with three replications of each, and four storage times (40, 80, 120 and 160 days). Recycled 2.6-L capacity plastic coffee containers were each loaded with 1 kg of maize and 25 live adult weevils/kg. Every 12 h, disturbed treatment containers were manually rolled through one circumference of the 15.6-cm container. At 40 d, live weevil numbers were significantly lower (ca. 46% lower) in the disturbed containers, and after 160 d, live weevil numbers had been reduced by 93% compared to control containers. Maize moisture did not vary significantly between treatments. Disturbed containers had significantly lower mechanical damage and broken corn and foreign material along with significantly higher test weights. This work suggests that physical disturbance may be effective for control of maize weevils in stored maize.

Keywords: maize, physical disturbance, post-harvest losses, maize weevil, test weight

INTRODUCTION

Maize is among the three most widely cultivated crops in the world (CIMMYT and IITA, 2011). In 2011, 35 million ha of maize was cultivated in Africa, and more than 170 million ha globally (FAOSTAT, 2014). Maize in combination with wheat and rice supplies 30% of the food calories to more than 4.5 billion people in 94 developing countries (von Braun et al., 2010). Thus, maize plays a critical role in the lives of millions of smallholder farmers.

In addition to increasing maize production, minimizing post-harvest losses (PHLs) can reduce the number of food insecure people who number 870 million, mostly (>97%) living in developing countries (FAO et al., 2012). A PHL reduction strategy is increasingly recognized as part of an integrated approach to meeting global food and energy needs (WorldBank et al., 2011; FAO, 2014). PHL reduction makes more grain available without additional labor, seeds, and land. The majority of PHLs occurs during storage, and maize weevil (*Sitophillus zeamais*) is the prominent insect responsible for PHLs of stored maize in the tropics (Longstaff, 1981; Longstaff, 1986; Jacobs and Calvin, 2001).

There are multiple approaches to control maize weevil damage during storage of grain on smallholder farms. One obvious approach involves insecticides, but they present safety concerns and other problems (Phillips and Throne, 2010). Hermetic storage controls weevils by limiting their oxygen supply (Yakubu et al., 2011), and does not carry with it any risk to the smallholder farmers who apply it, but maintaining hermetic sealing is difficult.

There has been some research done to investigate the effects of physical disturbances on insect survival in stored products. Bailey (1969) found that physical disturbance of wheat stored with grain weevils (*Sitophilus granaries)* hinders their development. Quentin et al.

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(1991) working with common beans infested with the common bean weevil, *acanthoscelides obtectus* (Say) investigated the effect of bean tumbling to control storage losses. They hypothesized that when beans are physically disturbed numerous times, weevil larvae die due to exhaustion before gaining access to the cotyledon. The experiment consisted of tumbling storage containers loaded with beans containing bean bruchids every eight hours. A 95% or greater overall mean reduction in bean bruchid population was achieved due to storage container physical disturbance.

We found no reports of using physical disturbance to control insects in stored maize. The objective of this research was to determine the effects of storage container physical disturbance on maize weevil mortality and maize quality.

METHODS AND MATERIALS

Containers

Recycled 2.6-L plastic ground coffee containers were used for this experiment (Figure 1). One 10-cm diameter round hole was cut through each lid and then ultra-sun block solar screens (New York wire, P.O. Box 866, Mt. Wolf, PA 17347, USA) were glued over the holes with silicon glue to allow air circulation while preventing escape of weevils. Lids were held in place by use of two rubber bands per container.

Maize and weevils

Commercial comingled bulk maize used in the experiment was purchased from West Central Coop Elevator (1095 T Ave, Boone, IA 50036). Each container was loaded with 1kg of 13.6% (w.b.) moisture maize which occupied about 75% of container volume. Maize weevils *(S. zeamais)* were from a supply maintained by the Department of Agricultural and Biosystems Engineering at Iowa State University.

Experimental design

The experiment consisted of two treatments: control containers and disturbed containers (Figure 1), with three replications of each container, and four different storage times (40, 80, 120 and 160 days), totaling 2x3x4=24 containers. Twenty five live adult weevils were loaded into each of the containers, which were stored in a 27^{0}C room. Every 12h, the disturbed treatment containers were manually rolled through one circumference (49 cm).

Measurements and analysis

After 40, 80, 120, and 160 d, three control containers and three disturbed containers were picked randomly for data collection. Weevil mortality was determined per Gullan and Cranston, 2010 and container contents were analyzed for broken maize and foreign material (BCFM) (USDA, 2013), moisture content (ASABE, 2006), test weight (TW) (USDA, 1996) and visible mechanical damage (MD) (Steele et al., 1969). A two-way ANOVA was carried out and then Tukey's means comparison was used to detect statistical significance at α=0.05 using JMP Pro 10.

RESULTS AND DISCUSSION

Live weevils

At 40 d, live maize weevil mean declined from 25 to 11±1 in the control, and 6±3 in the disturbed treatment, however this difference between treatments was not statistically significant (Table 1). By day 80, control population rebounded to 15±2, while disturbed treatment population dropped further to 1±2, where it remained through day 120. Disturbed treatment population reached 3±2 after 160 d. It is unclear whether this slowly increasing trend would continue if the experiment was longer. For 120 and 160 day time periods, control containers showed a continued increase in the number of live weevils whereas disturbed container numbers remained low. There was a significant effect of the time of storage ($F_{3, 1, 3}$ = 16.78, p<0.0001) and treatment ($F_{3, 1, 3}$ = 155.24, p<0.0001) on the number of live weevils.

The interaction between time and treatment was significant ($F_{3,1,3}$ = 20.72, p<0.0001). The significance of the interaction would be expected as disturbance continues because the weevils are increasingly unable to reproduce. Live weevil means were not significantly different at 0 and 40 d between treatments and controls but there were significantly higher for the control at 80 (p=0.0016), 120 (p=0.0030), and 160 d (p=0.0006). After 160 days, live weevil means were 7% of those in the control containers. Analysis of the results with time was also done for each treatment (Table 1). In the control treatment, there were no significant differences between 0, 40, and 80 days. Live weevil means were not significantly different between 120 and 160 days, but these values were significantly higher than those for 0, 40, and 80 days. Disturbed treatment means were significantly lower at all times after 0 days.

Our results are similar to those reported for stored beans (Quentin et al., 1991). Based on our results, to scale up this approach to control maize weevils may be somehow challenging because the storage containers need baffles inside for effective mixing when turning and there may be a need of frame support to hold the container to be physically disturbed. Future work should investigate storage container capacity typical of small holder farmers like 208-L (55-gal) steel barrels with and without baffles, and with and without frame supports. Also growth stage/age of maize weevils should be monitored in future research work.

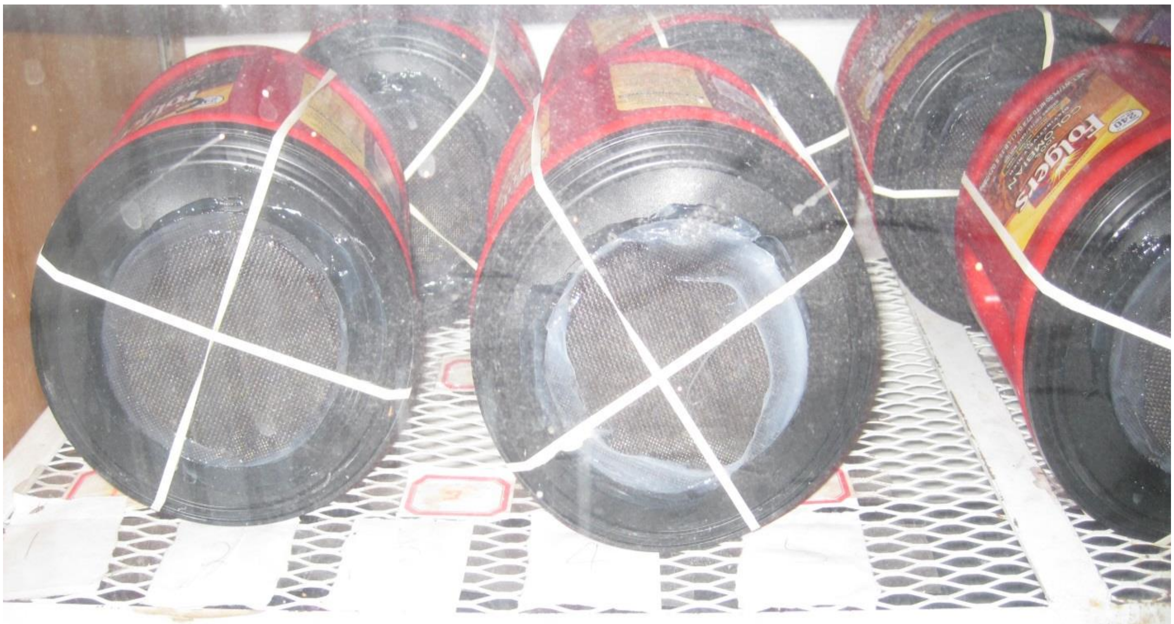

Figure 1. Maize containers.

Table 1. Means comparison of live weevils and maize quality parameters for physical disturbance versus control experiment.

Item	Treatment	T=0 d	T=40 d	T=80 d	T=120 d	T=160 d
Number of live weevils/kg	Control	25±0^{Ab}	11±1^{Ab}	15±2^{Ab}	40±8^{Aa}	44±5^{Aa}
	Disturbed	25±0^{Aa}	6±3^{Ab}	1±2^{Bb}	1±2^{Bb}	3±2^{Bb}
MC (%)	Control	13.7±0.2^{Ma}	13.5±0.2^{Ma}	13.3±0.1^{Ma}	13.4±0.2^{Ma}	13.2±0.2^{Ma}
	Disturbed	13.7±0.1^{Ma}	13.5±0.2^{Mab}	13.3±0.2^{Mabc}	13.2±0.1^{Mbc}	13.0±0.0^{Mc}
MD (%)	Control	14.4±0.5^{Gc}	16.1±1.3^{Gc}	16.8±0.7^{Gbc}	20.1±1.8^{Gab}	22.0±0.4^{Ga}
	Disturbed	14.7±0.3^{Ga}	15.3±0.5^{Ga}	15.1±0.1^{Ha}	15.1±0.2^{Ha}	14.1±0.1^{Ha}
BCFM (%)	Control	0.0±0.0^{Kb}	0.57±0.1^{Ka}	0.60±0.1^{Ka}	0.82±0.2^{Ka}	0.96±0.2^{Ka}
	Disturbed	0.0±0.0^{Kb}	0.59±0.1^{Ka}	0.68±0.0^{Ka}	0.65±0.2^{Ka}	0.45±0.0^{La}
TW (1b/bu)	Control	56.7±0.0^{Ra}	56.6±0.0^{Rab}	56.5±0.0^{Rab}	56.3±0.2^{Rbc}	56.1±0.1^{Rc}
	Disturbed	56.7±0.1^{Ra}	56.6±0.1^{Ra}	56.5±0.1^{Ra}	56.5±0.1^{Ra}	56.5±0.1^{Sa}

Means not followed by same upper case letter within each treatment, and means not followed by same lower case letter at each time for each item are significantly different at 0.05 level.

Maize Moisture

Maize moisture means during the experiment ranged between 13.0% and 13.7% w.b (Table 1). Moisture content did not differ significantly between control and disturbed treatments at any time during the experiment. Time of storage showed significant effect of on MC ($F_{3, 1, 3}$ = 4.02, p =0.0261) although treatment showed no significant effect of ($F_{3, 1, 3}$ = 1.74, p=0.2053) on moisture content. The interaction between time and treatment was not significant ($F_{3, 1, 3}$ = 0.34, p=0.7966). Control moisture content did not differ significantly between any time periods. In the disturbed samples, moisture exhibited a continual decline and the level at 160 d was significantly lower than at 0 d. Maize in the disturbed containers had fewer and fewer weevils to add moisture and was approaching equilibrium with the environment. Whereas increasing weevil numbers in the control containers were adding moisture to counter this trend.

Maize quality

At the beginning of the experiment, 14 to 15% of the maize kernels showed visible mechanical damage. Maize in the control containers showed increasing levels of damage, presumably due to maize weevil activity, whereas physically disturbed storage containers showed no significant increases with time (Table 1), despite the additional mechanical stress to which kernels were subjected. Damage levels in control samples became significantly greater after 80 d. The increasing damage trend for control samples was attributed to the increasing number of maize weevils that cause more damage to kernels whereas the constant levels in the disturbed samples reflect the declining number of weevils as expected. There was a significant effect of the time of storage ($F_{3, 1, 3}$ = 11.54, p=0.0003) and treatment ($F_{3, 1, 3}$ = 78.09, p<0.0001) on mechanical damage. The interaction between time and treatment was significant ($F_{3, 1, 3}$ = 13.92, p =0.0001). The significance of the interaction was expected as disturbance proceeds, the weevils are increasingly unable to reproduce thus less mechanical damage. Mechanical damage between treatments was not significantly different at 0 and 40 d but was significantly higher for the control treatment at 80 (p=0.0297), 120 (p=0.0176), and 160 d (p<0.0001). Our findings are consistent with the literature: When Cotton and Gray, 1948 and Joffe, 1963 periodically transferred large stores of grain from one bin to another, they noticed reduced pest damage following this physical disturbance. A major effect of grain transfer and/or disturbance is to reduce damage impacts by insects (Joffe and Clarke, 1963; Bailey, 1969; Loschiavo, 1978). Broken maize and foreign material (BCFM) means ranged between 0.0% and 0.96% over 160 d (Table 1). There was no significant effect of time of storage ($F_{3, 1, 3}$ = 1.09, p=0.382), though a significant effect of treatment ($F_{3, 1, 3}$ = 4.79, p=0.044) on BCFM was detected. The interaction between time and treatment was significant ($F_{3, 1, 3}$ = 4.02, p=0.026). Both control and disturbed BCFM levels were significantly higher after 40 d, but neither increased significantly after that. BCFM means between treatments were not significantly different at 0, 40, 80, and 120 d but the mean was significantly higher for control samples at 160 d (p=0.0162). We suspect this higher level reflects activity of the increasing weevil populations in the control samples.

Test weight means ranged between 56.7 to 56.1 1b/bu over the 160 d of the experiment (Table 1). There was a significant effect of storage time ($F_{3, 1, 3}$ = 6.92, p=0.0034) and treatment ($F_{3, 1, 3}$ = 8.03, p=0.0120) on TW. The interaction between time and treatment was significant ($F_{3, 1, 3}$ = 3.29, p=0.0480). The significance of the interaction was probable as disturbance proceeds, the weevils are increasingly unable to reproduce to affect TW. Physically disturbed container test weights did not change significantly with time over the entire experiment. Control treatment test weights were significantly lower after 160 d, compared to the mean at 0 d. Test weight means between treatments were not significantly different at 0, 40, 80, and 120 d but were significantly higher for the disturbed samples at 160 d (p=0.0257).

CONCLUSIONS

The following conclusions can be drawn from the study:

– Disturbance of storage containers reduced adult maize weevil populations significantly after 40 d and by 93% after 160 d compared to control populations.

– Maize quality in disturbed containers remained the same or better than in control containers.

– Physical disturbance shows promise as a useful way to control maize weevils and maintain maize quality in stored maize.

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