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Artificial cooling to control coleopterans in paddy rice stored in metallic silo

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Abstract

Stored paddy rice may be infested with insect pests that reduce its quality and quantity, causing economic losses to the grain industry. The objective of this research was to evaluate the use of chilling aeration to control insects in stored rice. In a 5,000 t metallic silo filled with paddy rice, a commercial grain chiller was installed to insufflate cold air through the aeration system of the silo. The insect monitoring was done every 15 days using probe traps into the grain mass and baited cages on the floor outside the silos in the storage facility. Among the species captured in the probe traps were the following Coleoptera: *Oryzaephilus surinamensis* (60 %); *Cryptolestes ferrugineus* (9 %); *Rhyzopertha dominica* (16.5 %) and *Sitophilus* spp. (0.5 %). The captures increased about 21 % in 15 days after treatment because the insects migrate from bottom to the surface when the lower layers started to cool down. However, by the 28th day, when the average temperature of the grain mass was kept at about 15 ^{o}C, the insect number was reduced 76.8 %. The chilling aeration controlled the insect populations for about 60 days. After this period, another cycle of chilling aeration should have been applied to avoid insect development to keep the grain in a safe temperature level. It was verified the need for a proper structure and silo preparation before receiving the new crop. Grain management, including monitoring of the insect populations and temperature should be observed to avoid re-infestation and to guarantee the efficacy of the cooling treatment.

Key words: Grain cooling; physical control; stored product insects; stored rice.

Introduction

Rice grain is subject to physical, sanitary and nutritional losses from physiological maturity, in the field, until the consumer level. These quality changes are caused by fungi, insects and handling during harvesting, receiving, drying, storage and/or grain processing, resulting in financial losses to the grain elevator, food industry, and to the consumers (Lazzari, 1997; Lazzari and Lazzari, 2002).

Among the alternatives to control insects in stored paddy rice, the artificial chilling represents a very promising tool to suppress insect population and keep grain quality, especially in warm and humid regions. Artificial chilling consists of insufflations of cool air (about 12 °C) at high volumes and low speed throughout the grain mass. It has application to the overall seed and grain industry, especially for consumers that do not accept any chemical residue in the end-product, such as organic food and specialty grains.

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In general, low temperature keeps the seed or grain quality and shelf life of almost any product for a long period of time, reducing insect and mold activities (Carvalho and Silva, 1994; Lazzari, 1997) and keeping seed vigor and germination.

In rice producing areas, aeration with ambient air is not sufficient to control insect infestation, therefore insecticide application will be required (Moreira, 1993). In cold clime regions, grain cooling can be done by using natural ambient air. According to Fields and Muir (1996) and Maier (1994, 2002), grain chilling allows safe storage and reduction of insecticide application.

Artificial grain chilling using an air conditioning machine does not depend on external climatic conditions and can be applied in most regions at any, time of the year. Thompson (1972) presents a description of several systems that can be used to chill commodities.

According to Moreira (1993), grain artificial cooling is obtained when the grain mass temperature is lower than the outside air temperature by using a refrigerated air system. Grain with 16-18 % moisture content (wet basis) can be stored from 3-18 months by reducing grain temperature to 3-10°C, inhibiting insects, molds, and loss on seed vigor and germination.

The effect of temperature on development and reproduction of insects has been studied and revised by Howe (1965), Fields (1992), Prakash and Rao (1995) and Subramanyam and Roesli (2000). However, little large-scale research is available. According to Fields (1992), the optimum temperature for the development of major insect pests of stored products is about 25-33 °C. Insect control by using high temperature, such as warming the grain to 55-65 °C, as well as low temperature at 10-12 °C, represents a strategy to reduce insect infestation in grain facilities.

According to Banks and Fields (1995), reduction of grain temperature from 20 to 14 °C by insufflating cold air into the grain mass affects the development of the major insect species and increases their mortality, especially during the immature stages.

Probe traps, pheromone and cage traps are very useful tools for insect monitoring. Pereira et al. (1999) used them in stored corn, Paula et al. (2002) and Trematerra et al. (2004), in stored paddy rice.

The general objectives of this research were to evaluate the efficacy of a commercial grain chiller to control insect pests in paddy rice in a large metallic silo and the usefulness of insect trapping as a control decision tool.

Materials and methods

The experiment was carried out in a rice storage facility in the county of Massaranduba, State of Santa Catarina, Brazil (26° 37’ 28" S and 49° 01’ 48" W; 29 m above sea level) (Figure 1). The clime is mesothermic humid, with hot summers and average annual temperature of 20.1 °C.

The treatment was carried in a metallic silo filled with 5,000 tons of paddy rice from the previous and the year crops. The grain was heavily infested with several coleopteran species and the moisture content was about 13.0 %, by the time the tests were started. The grain chilling treatment was started on April 13,

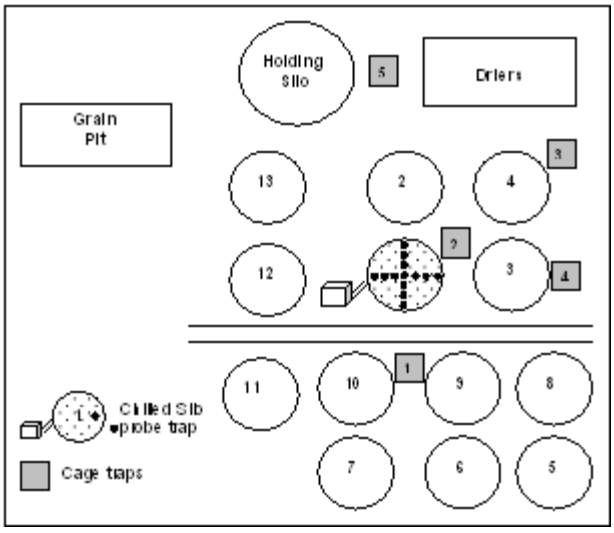

Figure 1. Map of the rice storage facility where experiments were carried out, in Massaranduba, State of Santa Catarina, Brazil (not in scale).

2002, with an airflow of 10,000 m^3/h and the air temperature at 10-12 °C, during 240 hours, running the chiller day and night. The cold air was produced by an equipment model (COOLSEED-PCS40®) with nominal refrigeration capacity of 121,212 Kcal/h. This grain chiller is manufactured in State of Parana, Brazil (Figure 2).

One week before treatment, thirteen probe traps (Figure 3a) were installed on the surface of the grain mass, 30 cm deep, following the cardinal orientation as shown on Figure 1. The day before grain chilling, the traps were removed for insect counting. After that, trapping evaluation was carried out every 15 days. Insects captured in the probe traps were placed in plastic bags with date of sampling, and frozen for insect counting and identification.

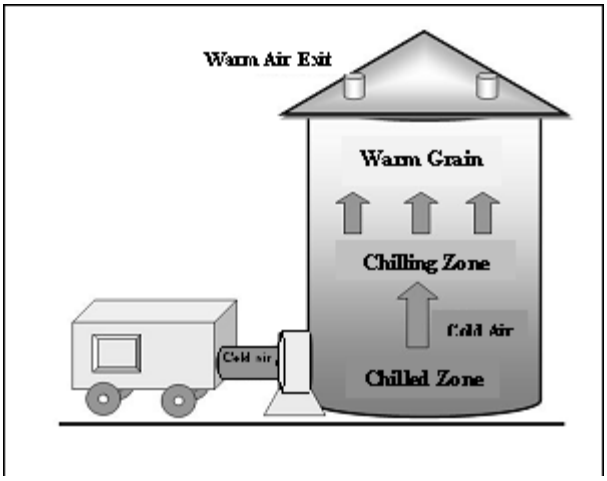

Figure 2. Grain chiller insufflating cold air through the aeration system of the silo.

The sampling data that was taken before treatment was used as the control. The grain mass temperature was taken using five thermocouples with sensors at 1.8 m distant from each other.

To evaluate insect infestation outside the silo, five baited cage traps (Figure 3b) were installed at different points of grain facility (Figure 1). The bait was composed of 2 parts of whole rice kernels, two parts of coarse broken corn kernels and one part of wheat germ. The bait was changed every fifteen days for insect counting and identification. Moisture content was measured using a Motomco meter.

Data was analyzed using Shapiro-Wilks Test and mean comparisons by "t" test of Student for samples following normal distribution using the STATGRAPHICS plus 5.0. The hypothesis analysis was done at 5 % of probability: H_0 = insect number after treatment is equal to that in the control (before treatment); H_1 = insect number after treatment is different from that in the control. The hypothesis analysis was done separately for each insect species.

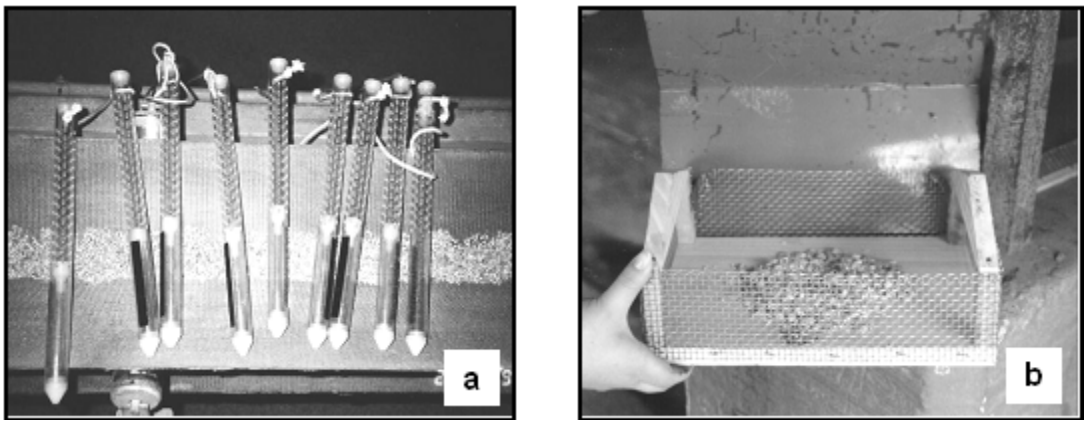

Figure 3. (a) Probe traps used for insect monitoring in paddy rice; (b) Baited cage traps for insect monitoring in grain facility (Pictures by M.C.Z. de Paula).

Results

The main insect species captured by the probe traps were the following Coleoptera: *Sitophilus oryzae* (Linnaeus, 1763) and *Sitophilus zeamais* Motschulsky, 1855 (Curculionidae), *Rhyzopertha dominica* (Fabricius, 1792) (Bostrichidae), *Cryptolestes ferrugineus* (Stephens, 1831) (Cucujidae), *Oryzaephilus surinamensis* (Linnaeus, 1758) (Silvanidae) and *Tribolium castaneum* (Herbst, 1797) (Tenebrionidae). Other insects species either associated to storage grain or not were sampled in smaller numbers.

The average number of insects collected with probe traps was very high before treatment, 767/trap. Fourteen days after grain chilling, this number increased 21 % because insects moved up to the warmest portion of the grain mass where the traps were placed. Average temperature inside the grain mass dropped 76.8 %, ranging from 14.5 to 16 °C in this period. After about 30 days, insect averaged 178 specimens/trap. However, after about 54 days from treatment, the temperature started to increase again and the insect population reached levels as high as the ones before treatment (Table 1).

By the hypothesis analysis (H_0: $\mu_1 = \mu_{2,3,4,5,6}$), at 5 % probability, the null hypothesis is accepted when comparing the control (sampling 1 – before the chilling treatment) to the 3rd and 4th sampling dates, when all insect species had their population reduced by the cold. Despite the increasing insect number, the difference between the second sampling and control was not significant.

Oryzaephilus surinamesis was the most abundant species found in this stored rice silo, and it was affected by chilling aeration, with a significant population reduction by the third and fourth samplings. After that, its population increased back again, when the grain started to warm up, however, it did not reach the previous number. The same was observed for all the other species. Populations of *S. Oryzae* and *S. Zeamais* were counted together and were in relatively low number. They followed the same pattern – decreasing when grain was cold and increasing gradually and significantly when the effect of cold ended. For *R. Dominica*, population also increased significantly to very high numbers when the grain mass warmed up again. This indicates that this species should be monitored and kept under control.

The rusty grain beetle, *C. Ferrugineus*, and other insect species, such as *T. castaneum Plodia* spp. (Lepidoptera: Pyralidae), predator hemipterous and ants (counted together for this analysis) followed the same pattern in relation to temperature, either increasing or decreasing. Among these species, predator hemipterous were at a significant large number in the last sampling

Table 1. Total number of insects captured with probe traps and average temperature in paddy rice stored in a metallic silo treated with cold air produced artificially, Massaranduba, State of Santa Catarina, Brazil, 2002.

Sampling date	Average temp. in grain mass °C	Average temp. at grain surface °C	*Sitophilus oryzae*	*Rhyzopertha dominica*	*Oryzaephilus surinamensis*	*Cryptolestes ferrugineus*	Other insects	Total Insects
April 12	26.6	27.2	27	64	8,665	1,170	49	9,975 b
April 27	13.9	15.0	15	53	10,228	2,224	131	12,651 b
May 10	14.5	18.8	12	23	1,833	440	12	2,320 a
May 24	15.2	16.0	21	63	2,923	381	39	3,427 a
June 07	16.0	23.0	49	610	5,875	281	174	6,989 ab
June 21	16.8	18.4	60	2,261	7,710	256	1,609	11,896 b
July 06	19.4	22.8	89	8,827	6,223	1,753	8,028	24,920 c
Total			273	11,901	43,457	6,505	10,042	72,178

date. This happen while the other species were also abundant and grain temperature near the surface was as high as 20 °C.

Moisture content did not change significantly during the experiment period, increasing from 13.0 % to 14.0 %.

The cage traps distributed around the silo and in the storage facility catched several insect species (Table 2). The most numerous species were: *R. dominica* (56.7 %), *Sitophilus* spp. (14.5 %), *C. ferrugineus* (14 %), *O. surinamensis* (6.5 %) and *T. castaneum* (2.5 %). Variance analysis comparing the number of insects captured on the cage traps is shown on Table 3. Infestation was larger in grain pits, cleaning machines, in the grain bucket elevators and wherever there was spilled grain. *R. dominica* and *Sitophilus* spp. were more abundant in cage traps than in the probe traps, indicating that they could migrate from outside the silo and infest the grain mass.

Discussion

Despite the increase on insect number in the first evaluation (14 days after chilling treatment), the difference with the control was not significant. The increase was due to insect migration to the surface where the grain was still cooling down and where the probe traps were placed. The insect number decreased significantly in the 3rd and 4th sampling dates because, according to Banks and Fields (1995), reduction of grain temperature from 20 to about 14 °C affects the development and increases mortality of major insect species.

The data indicates that a 2nd application of chilling aeration was necessary after about 60 days when temperature and the number of insects start to increase. If the silo had been better prepared, cleaned inside and outside, inert dust applied in internal and external walls of the bin, and in bottom and top layer of the rice mass, the results would be better. Besides those practices,

Table 2. Insect species captured in five baited cage traps in a rice storage facility, in Massaranduba, State of Santa Catarina, Brazil, 2002.

Cage trap	*Sitophilus* spp.	*Rhyzopertha dominica*	*Tribolium castaneum*	*Oryzaephilus surinamensis*	*Cryptolestes ferrugineus*	Other insects	Total
1	1,939	3,806	465	35	1,015	1,060	8,320
2	367	2,774	16	2,018	1,544	329	7,048
3	2,656	2,525	216	95	990	255	6,737
4	138	5,660	2	199	1,529	98	7,626
5	173	5,861	207	8	153	233	6,635
Total	5,273	20,626	906	2355	5,231	1,975	36,366
%	14.5	56.7	2.5	6.5	14.4	5.4	100

Table 3. Variance analysis of the number of insects captured with five baited cage traps in seven collecting dates in a rice storage facility in Massaranduba, State of Santa Catarina, Brazil, 2002.

Source of variation	Degrees of freedom	Square sums	Average squares	F*
Cage traps	4	280226.1129	70206.52823	0.2364
Sampling date	6	3174943.37	529157.2283	1.78
Error	24	7126445.487	296935.2286	-
Total	34	10582214.97	-	-

* F values indicate that there is no statistics difference between treatments, at 5 % probability.

if another cycle of chilling aeration had been applied it certainly would extend the storage period without the need of fumigation or insecticide application. Thermometry and insect trapping give the necessary information for decision about when one should apply chilling aeration. The ideal would be to keep the average temperature in the range between 14-16 °C.

In addition, in regions where clime is hot and humid, additional chilling aeration cycles should be applied during the year if the storage manager decided not to use residual insecticides or fumigation.

The data from the cage traps are in accordance with Pereira et al. (1999), Paula et al. (2002) and Trematerra et al. (2004). It was observed that insect monitoring using cage traps provide useful information to draw a risk map to direct sanitation measures in the storage facility.

Comparing the data from both types of traps, it is observed that the probes collected larger numbers of *O. surinamensis* than the cage traps, whereas *R. dominica* and *Sitophilus* spp. were more numerous in the cage traps. It may indicate that these primary species are coming from some source of infestation inside the grain receiving area (grain pit, machines, elevators, deposits) and are infesting the silos. For *C. ferrugineus*, insect number was similar in both types of traps. The insect distribution maps inside a grain facility presented by Trematerra et al. (2004) indicates the predominance of *S. oryzae* in cage traps placed near the grain pit and in areas with intense movement of grain.

It is suggested that other studies should be carried out considering: regional clime, altitude, temperature, type of silo, size, height of the grain mass, aeration area on the bottom of the silo, volume of the chilled air necessary to cool the grain mass, time to cool and other factors. All these are important to improve this technology in areas were there is not enough days with cold air for natural aeration.

Based on our research it is possible to conclude that chilling aeration is a very useful insect control measure in stored rice. However, it is necessary to associate this technology with other practices and make decisions based on insect trapping and temperature records of the grain mass to achieve successful results.

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