Spatial distribution of stored grain insects in a rice storage and processing facility in Brazil

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Abstract

This study describes the spatial distribution of stored product insects captured biweekly using food-baited cage traps in a large rice storage and processing facility, in the state of Rio Grande do Sul, Brazil. Monitoring started in August 2009 and will be carried out for 1 year, the first 5 months of sampling being presented in this study. From end of August 2009 until the end of December 2009, a total of 9893 insects were captured in the 99 cage traps. The most abundant species were: *Carpophilus* spp. (76%), *Typhaea stercorea* (8.6%), *Ahasverus advena* (5.5%), *Tribolium castaneum* (2.3%), *Sitophilus oryzae* (2%), *Sitophilus zeamais* (1.5%), *Ephestia* spp. (1.2 %), *Cryptolestes ferrugineus* (1%), *Rhyzopertha dominica* (0.64%), *Oryzaephilus surinamensis* (0.6%), *Anthicus floralis* (0.4%), *Lasioderma serricorne* (0.25%). The first two species, which make up for 84.6% of the insects collected, are not considered pests in stored grain, rather are attracted by moldy material present in residues or even in the bait material. The other insects, including primary and secondary species, comprised about 15% of the total trapped. The spatial distribution of the most important species infesting rice grain and of the total insect number was analyzed using Surfer 6.04 (Golden software, Golden, CO, USA) and contour maps were constructed to target areas for sanitation. Except for trap 66, located by the rice hulk storage box, the spatial distribution we observed using the contour maps showed that the greatest number of insects was mostly captured in cages placed in the receiving area, around the dryers, as well as outside of the structure where grain residues frequently accumulate. As indicated on the maps for total number of insects, a few isolated infested spots were detected. The parboiled rice area had the least amount of insects, except for trap 61, placed outside the structure. The population of primary and the most important secondary insect species, as well as the overall number of insects, decreased after sanitation and physical control measures were applied. Our observations confirm that insect monitoring is an essential tool for targeting and evaluating the control measures adopted in the quality program of rice storage and processing facilities.

Keywords: Insect monitoring; Spatial distribution; Stored grain pests; Stored rice

1. Introduction

Rice, *Oryza sativa* (Poaceae), is one of the main food sources for people all over the world. According to FAO (2010), in 2008 the world produced 685 million tons (mt) of rice, 622 mt in Asia alone. Brazil was the 10th largest producer with 12 mt in 2008. The state of Rio Grande do Sul was the largest rice producer in Brazil with 7905 thousand t and a productivity of 7.15 Kg/ha in 2008, the highest in the country (FAO, 2009; CONAB, 2010).

The control of insect and mite pests in stored rice using fumigation and residual insecticides is still the most common practice in Brazil, these methods, however, may not be the most cost-effective. In addition, the residues of the active ingredients can cause contamination of the environment and health concerns with workers that are exposed to these chemical insecticides (Lorini, 1997; Fields and White, 2002). In addition, the resistance of insect populations to chemical insecticides has been documented in many countries (Subramanyam and Hagstrum, 1995; Collins et al., 2000). In fact, insect resistance has become a grave concern in some parts of the world, where only a few commercial insecticides are available.

Instead of scheduled pesticide applications, integrated pest management (IPM) uses a cost-benefit analysis to make decisions on when and how to perform pest control (Hagstrum and Flinn, 1996; Hagstrum and Subramanyam, 2000). These decisions, when possible, resort to alternative methods such as the use of resistant varieties (Throne et al., 2000), aeration (Reed and Arthur, 2000), low and high temperatures (Evans, 1986; Fields, 1992; Pinto Jr., 1999; Ceruti and Lazzari, 2005; Fields, 2006; Lazzari et al., 2006; Beckett et al., 2007), inert dusts (Jayas, 1995; Subramanyam and Roesli, 2000; Lorini et al., 2002; Athanassiou, 2005; Lazzari and Ribeiro-Costa, 2006), natural enemies (Kistler, 1985), and other integrated measures of managing pests. The issue is that the management of stored product pests, especially insects and mites, using these non-chemical techniques, requires greater knowledge and training in pest biology, behavior, ecology, population dynamics, spatial distribution compared to conventional chemical insecticides (Hagstrum and Subramanyam, 2009).

Post harvest IPM focuses primarily on structural modifications, sanitation of the facilities, and targeted pest control. Clean and sanitized structures are less likely to be favorable to pest establishment (Subramanyam et al., 2005; Campbell et al., 2006).

In IPM programs, monitoring is one of the most important approaches used when making decisions on pest control tactics. Monitoring usually requires trapping, not for the purpose of catching as many pests as possible, but to accurately monitor the population levels and to obtain data on the pest populations and their spatial-temporal dynamics (Arbogast et al., 1998). At first, it might seem like a costly and time consuming operation, however, applying pesticide treatments when they are unneeded, may add unnecessary to the cost to the pest management operation.

Targeting pest management to the places where the pests are located, in or outside a structure, increases the probability of suppressing that population and it is usually less costly and risky (Brenner et al., 2006).

As well as sanitation and monitoring insect activity and presence with traps, contour mapping can also be a very important tool in IPM. Techniques for spatial analysis applied to entomology provide a powerful tool and can impart crucial information to assist in biological interpretation of trap captures. In contour analysis, data are first entered on a map as a series of sample points. A denser grid of data points is then generated by interpolation, what can be done using several different algorithms. Subsequently, lines are drawn between points of equal value. These lines are called contours and are used to estimate insect population density in areas that have not been sampled (Arbogast et al., 1998; Trematerra et al., 2004).

The objective of this study was to monitor insect infestations in and around a rice facility and thus determine areas of risk that need more emphasis on cleaning and other safe and efficient insect control methods.

2. Materials and methods

The study was conducted in the largest rice storage, processing and packaging facility in Brazil, located in a single location in the city of São Borja, State of Rio Grande do Sul, southern Brazil. This rice processing plant is located at 28°39'38"S; 56°00'16"W; and 96 m asl. The climate, according to the Köppen-Geiger climate classification system, is Cfa subtropical humid. The facility contains several holding silos for wet rice, 56 metallic silos for storage and a white rice and a parboil rice plant.

A total of 99 food-baited cage traps, similar to those used by Throne and Cline (1991), and adapted by Pereira (1999), were placed around the structure, of which 44 were placed around the silos, 34 in the white rice plant and 21 in the parboil rice plant (Fig. 1). The bait consisted of 2 parts of whole corn kernels, 2 parts of broken corn kernels, 1 part of whole rice, 2 parts of broken rice and 1 part of wheat germ, previously sifted and frozen for 7 d at -18°C to kill any insects present in the raw material. About 150 g of bait were placed in a foil pan on the bottom of each cage and removed, whenever possible, every 15 days and the captured insects were counted and identified. Monitoring started on August 2009 and will be continued for one year; however, for this paper only the first 5 months of monitoring are presented for the overall insect captures and 6 months for key rice pests.

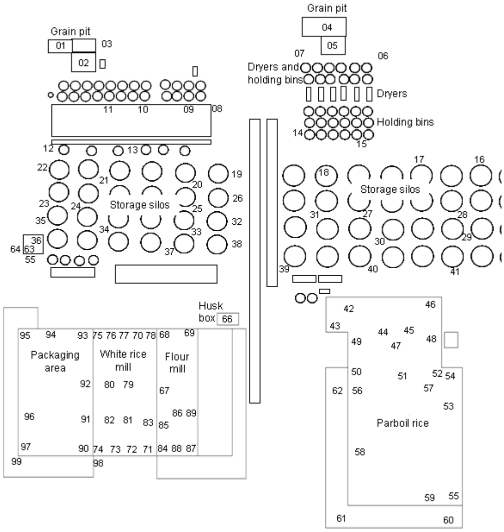

Figure 1 Food-baited cage trap distribution in the storage and processing areas of a rice facility in São Borja, Rio Grande do Sul, Brazil, from August 2009 to January 2010.

The spatial analysis was carried out using the program Surfer version 6.4 (Golden software, Golden, CO, USA). The x and y coordinates represent the position of the traps and z representing the total number of insects captured in a particular trap over a 15 d interval. By interpolating the z values using the interpolation algorithm linear Kriging with a zero nugget, Surfer produces a grid of values. The interpolation grid obtained is used to produce a contour map, which shows the configuration of the surface by means of isolines representing equal z values. Average temperature and relative humidity were recorded.

3. Results

A total of 9893 insects were captured with the food-baited cage traps from August until December 2009 (Table 1 and Fig. 2). The most abundant species were the sap beetles *Carpophilus* spp. (7527 specimens) and about 50% of them were collected in trap 66 on November 16. The second most abundant species was *Typhaea stercorea*, commonly known as hairy fungus beetle (857 specimens). These first two species represented about 85% of all captured insects until December 2009. Both pests are not direct pests of stored rice but may be associated with stored products, feeding mostly on molds and other decaying material. Several other insect species were captured, but in smaller numbers: *Ahasverus advena* (5.5%), *Tribolium castaneum* (2.3%), *Sitophilus oryzae* (2%), *Sitophilus zeamais* (1.5%), *Ephestia* spp. (1.2 %), *Cryptolestes ferrugineus* (1%), *Rhyzopertha dominica* (0.64%), *Oryzaephilus surinamensis* (0.6%), *Anthicus floralis* (0.4%), *Lasioderma serricorne* (0.25%).

Table 1 Species and number of insects captured with food-baited cage traps from August 2009 to December 2009 in a rice processing facility in São Borja, Rio Grande do Sul, Brazil.

	Date of collect							
Order/Family/Species	**Aug 27**	**Sep 10**	**Oct 02**	**Oct 13**	**Nov 16**	**Dec 14**	**Dec 26**	**Total**
Coleoptera								
Anobiidae								
Lasioderma serricorne (F., 1792)	1	3	4	3	56	0	31	117
Anthicidae								
Anthicus floralis (L., 1758)	10	11	15	1	2	3	1	43
Bostrichidae								
Rhyzopertha dominica (F., 1792)	10	2	8	4	10	8	21	63
Cucujidae								

	Date of collect							
Order/Family/Species	Aug 27	Sep 10	Oct 02	Oct 13	Nov 16	Dec 14	Dec 26	Total
Cryptolestes ferrugineus (Stephens, 1831)	1	1	14	23	41	17	5	102
Curculionidae								
Sitophilus oryzae (L., 1763)	78	61	22	26	5	6	2	200
Sitophilus zeamais Motschulsky, 1855	42	60	16	15	13	4	1	151
Mycetophagidae								
Typhaea stercorea (L., 1785)	62	154	139	86	145	156	95	837
Nitidulidae								
Carpophilus spp.	245	700	1005	443	3706	634	794	7527
Silvanidae								
Ahasverus advena (Waltl, 1834)	27	85	90	15	244	59	23	543
Oryzaephilus surinamensis (L., 1758)	13	4	0	0	39	0	0	56
Tenebrionidae								
Tribolium castaneum (Herbst, 1797)	115	28	8	1	70	4	4	229
Lepidoptera								
Pyralidae								
Ephestia spp.	20	3	4	3	56	0	31	117
Total	623	1112	1322	621	4341	897	977	9893

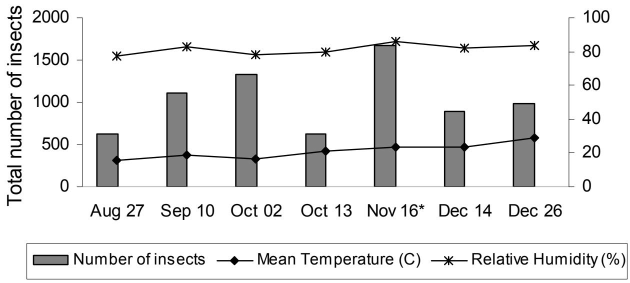

Figure 2 Total number of insects captured in food-baited cage traps compared to mean temperature and relative humidity in a rice facility in São Borja, Rio Grande do Sul, Brazil, from August 2009 to December 2009.

The most important insect pests that infest the rice grain, *S. oryzae*, *S. zeamais*, *R. dominica*, *T. castaneum* and *Ephestia* spp., added up to 7.6% of all insects captured. The population fluctuation of these species along the trapping period shows that in the first two collection dates, late August and early September, most of these species occurred in numbers higher than in the subsequent samplings (Fig. 3). After grain treatment and sanitation measures adopted in late September there was a decrease in the number of these insect species. In November, high population peaks of *T. castaneum* were recorded in trap 3 in the receiving area and of *Ephestia* spp. in traps 83 and 96 in the white rice milling and packaging areas (Fig. 3 and 4). In November, trap 61 captured a few *S. oryzae* on the outside of the parboil rice plant (Fig. 4).

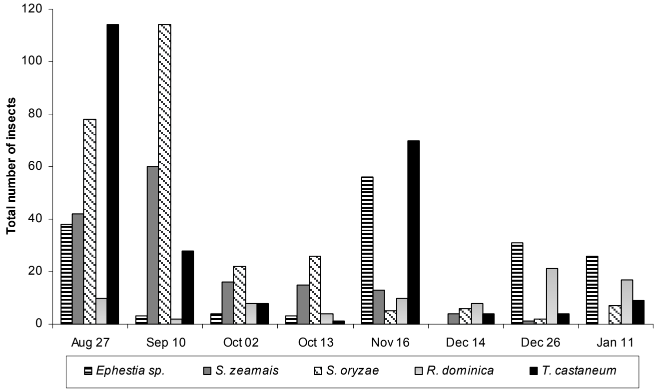

Figure 3 Total number of key insect pests for stored rice (*S. oryzae*, *S. zeamais*, *R. dominica*, *T. castaneum* and *Ephestia* spp) captured in food-baited cage traps in São Borja, Rio Grande do Sul, Brazil, from August 2009 to January 2010.

Even with increasing temperatures from December through January, the populations were maintained under control as result of sanitation and control measures.

Contour maps for the months of August, November and January were designed for these key species (Fig. 4). Trap 97 located in the white rice plant presented a high number of *T. castaneum* and trap 93 had a few *Ephestia* spp. in the August capture. For November and January there were no captures of *T. castaneum* in trap 97 and a decrease in captures of *Ephestia* spp. In the parboil rice plant, the November capture presented the largest number of insects. Trap 46 had a large number of *T. castaneum* and trap 61 had a large number of *Ephestia* spp. In January, trap 46 had no insects and trap 61 had only one *S. oryzae*. In the silo area, the capture for these key species was low in all three months. In November, there was an infestation point of *T. castaneum* in trap 3, near where the grain is received and dried. In January there was a large capture of *R. dominica* in trap 16.

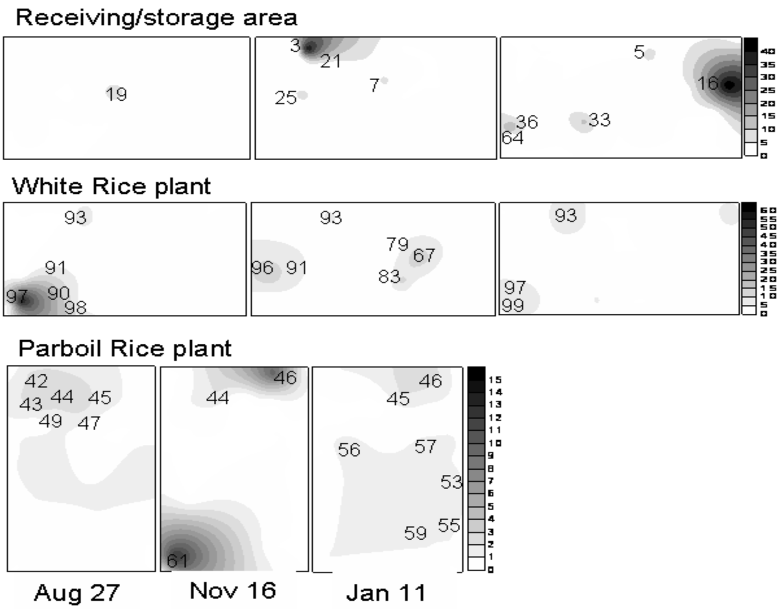

Figure 4 Spatial distribution of key pests for stored rice (*S. oryzae*, *S. zeamais*, *R. dominica*, *T. castaneum* and *Ephestia* spp.) captured in food-baited cage traps in the months of August, November and January, in São Borja, Rio Grande do Sul, Brazil. See Figure 1 for details of the rice plant.

The traps collected November 16th had the highest number of all captured insect species, but this was probably due to the long period of time that the traps remained in place without replacement (over 1 month).

Comparing the trap display in the receiving, drying and storage area (Fig. 1) to the contour map of the same area for the total number of captured insects (Fig. 5a), traps number 7, 14, 15 16, 22, 33 and 40 were the most infested, presenting a total of over 200 insects each. Traps 7, 14 and 15 are close to a pre-cleaning machine and the dryers and may represent a focus of infestation to the other traps nearby.

The contour map of the white rice plant (Fig. 5b) shows that this area had the largest number of insects, including traps 67 and 89, that are placed right in the rice flour milling area, and trap 98, which is placed just outside the plant (Fig. 1). Trap 66, on the outside north east corner of the white rice plant, was the trap that had the overall largest number of insects. On the November 16th collection alone, 2670 *Carpophilus* spp. were captured in that trap. Those insects were not plotted on Figure 1 to avoid overestimation of the data set.

Trap number 46 was the trap that had the largest amount of insects inside the parboil rice plant (Fig. 1 and 5c) and traps 61 and 62 had the largest amount of insects collected on the outside walls of the parboil rice structure, probably due to spillage.

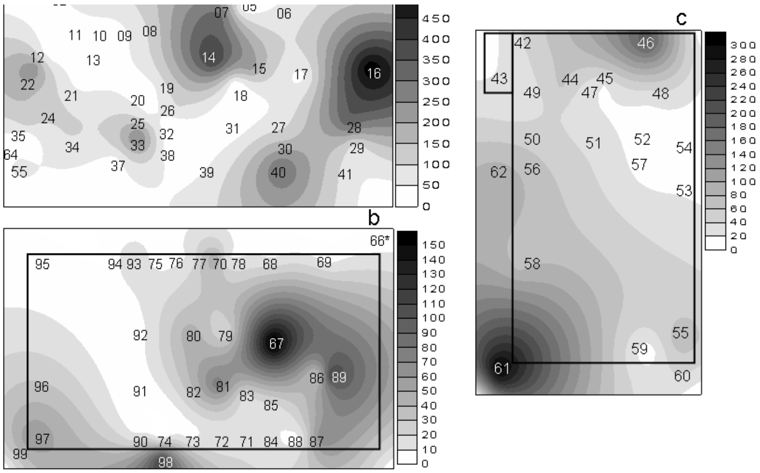

Figure 5 Spatial distribution of the total number of insects captured in 99 food-baited cage traps in the reception, drying and storage areas (a); white rice processing area (b); and parboil rice processing area (c), in São Borja, Rio Grande do Sul, Brazil, from August 2009 to December 2009. See Figure 1 for details of the rice plant.

4. Discussion

Monitoring with food-baited traps and the use of spatial maps of population distribution are two very important tools to detect insects in and around the structures to predict insect infestation and to target pest management. In this study key insect species infesting rice, as well as all insects occurring in rice storage and processing were monitored. Some of these insects, such as *Carpophilus* species, may not inflict direct damage to the grain, but they do indicate unsanitary conditions and present contamination if found in the final product.

The spatial distributions we observed through the contour maps indicate that the greatest number of insects were captured in places where the grain is received and dried, as well as where residues are stored and outside of the structure where grain spillage is common. Our results are similar to what Paula (2002), Pereira (1999), and Trematerra et al. (2004) reported for insect trapping in grain storage and processing facilities in southern Brazil. The different areas of the facility appear to have different species, populations, and infestation size. The parboil rice plants tend to have less infestation than the white rice plants and silos.

The results differ from what Trematerra et al. (2004) found in another rice storage facility in Massaranduba, State of Santa Catarina, as the various species did not show variable distribution in the same areas, and the populations seemed to remain in distinct parts of the structure. However, this characteristic might change for captures made during the coolest months of the year.

Even with the rising temperatures from August to December, the overall population of insects did not increase. This was due to the rigorous cleaning and sanitation measures that have been adopted since mid-September (Fig. 2). The entire structure, including silos and walls, were washed with high pressure water spray. The silos (3,500 t each) were thoroughly sprayed outside with a formulation of diatomaceous earth and deltamethrin before the new grain was added. The lower and upper 60 t of grain were dusted with powder DE plus deltamethrin during grain loading. Artificial chilled aeration was applied for about three days after the silo was loaded. The chilled air was introduced into the bin at 6 to 8ºC, and aeration continued until the grain mass reached 12 to 14ºC.

Basic cleaning measures, such as elimination of piles of old sacks, grain residues, garbage, other materials, and the cleaning of floors, machineries and silos before filling, as well as the control measures adopted resulted in an improvement in lowering the insect population. The real effects of these measures will be evaluated after a year of trapping. Samples of paddy rice have been taken periodically from the silos, but no insects have been observed in those samples.

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