Insect Population Growth in Stored Freshly Harvested Wheat (Coleoptera: Curculionidae & Silvanidae)

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Abstract. The temperature and insect population growth variation of freshly harvested wheat, stored in flat storehouses and steel bins (3000 t) have been investigated when using atmospheric air ventilation for cooling. At the temperature mode established, by the simulation models developed the rate of insect population growth of the rice weevil *Sitophilus oryzae* (Linnaeus, 1763) and the sawtoothed grain beetle *Oryzaephilus surinamensis* (Linnaeus, 1758) has been determined. The models validity is 78–95 % for both species of insect pests and both granaries. The insect population growth for both species has started after 23–33 days and continued up to 135 days in steel bins and respectively up to 111 and 95 days in the flat storehouses. The maximum values of numbers of *Sitophilus oryzae* and *Oryzaephilus surinamensis* populations in the flat storehouses are 60 and 80 times smaller as compared to those in the steel bin. Because of that, at grain storage in flat storehouses it is possible to abstain from fumigation.

Zusammenfassung. Das Wachstum von Insektenpopulationen in Abhängigkeit von der Temperatur bei Einsatz von Frischluft zur Ventilation und Kühlung wurde an frisch geerntetem Weizen in flachen Lagerhallen und Stahlsilos mit 3 000 t Fassungsvermögen untersucht. Dabei wurde das Populationswachstum zweier Käferarten, des Reiskäfes *Sitophilus oryzae* (Linnaeus, 1763) und des Getreideplattkäfers *Oryzaephilus surinamensis* (Linnaeus, 1758) ermittelt und mit einem Wachstumsmodell verglichen, was eine Übereinstimmung von 78–95 % für beide Schadkäferarten und Lagerungssysteme ergab. Das nachweisbare Wachstum der Populationen beider Arten begann nach 23–33 Tagen und konnte bis zu 135 Tage in den Stahlsilos und bis zu 111 bzw. 95 Tage in den Lagerhallen erfasst werden. Die maximale Populationsdichte von *Sitophilus oryzae* und *Oryzaephilus surinamensis* in den Lagerhallen ist 60 bzw. 80 mal kleiner als in den Stahlsilos. Daher kann bei der Lagerung in Hallen auf eine Begasung gegen Insektenbefall verzichtet werden.

Key words. Simulation model, flat storehouse, steel bin, population ecology, pest control.

Introduction

The freshly harvested wheat enters for storage with temperature usually of 30–33 °C. This temperature is within the optimum range for insect population development (27–34 °C), which infest grains since the first storage days (Hagstrum 2001, Vela-Coiffier et al. 1996). The high temperature is preserved for sufficiently long time (30–90 d) for the development of one to two generations of insect population and for the quick population growth. The duration of the period with high grain temperature depends on cooling time, which is not identical for the different concrete granaries.

The rate of insect population growth is important for undertaking timely measures for growth limitation or insect pests extermination. For its determination, simulation models for the growth of the different species of pests have been used, which have been based on data available on development time, fertility and death rate at different conditions (temperature and humidity of the nutritive medium). Such models have been developed for some insect pests as *Cryptolestes ferrugineus, Rhyzoperta dominica* and *Tribolium castaneum*, whose validity has been established at laboratory and production conditions (steel bins with 84 t capacity) at natural cooling of grain mass (H‡gstrum & Throne 1989). The model of *R. dominica* has been improved later on (Hagstrum 1996) by using new data for fertility and death rate and has been applied for forecasting the change of population density when storing wheat in a concrete granary – reinforced concrete unventilated silo (Flinn et al. 2004). Similar simulation models have been developed also for the insect pests *Oryzaephilus surinamensis* and *Sitophilus oryzae*, whose validity has been established at laboratory conditions, respectively at constant temperature and moisture and spring grain temperature increase (Hagstrum & Flinn 1990].

Besides for population growth determination, the simulation models are also used for comparison the efficiency of the different methods (ventilation, fumigation, etc.), applied against the pests (Arthur & Flinn 2000, Flinn et al. 1997, Hagstrum & Flinn 1990]. Their validity depends on the ecological data used for the pests and the storage conditions, in the different granaries they being not equal.

The purpose of this study is to determine the insect population growth rate of the most widely spread insect pests, the sawtoothed grain beetle *Oryzaephilus surinamensis* (Linnaeus, 1758) and the rice weevil *Sitophilus oryzae* (Linnaeus, 1763), when storing freshly harvested wheat in flat storehouses and steel bins with great capacity (3000 t), at conditions of grain mass cooling by atmospheric air ventilation.

Materials and Methods

In order to accomplish our purpose we have made growth simulation for both species of insect pests according to the way described in the above-described sources, with the only difference that we have used data concerning the development time of the separate stages obtained during investigations, carried out in Bulgaria, by May Van Le (1976) and Obretenchev (1986), respectively. On the basis of these data regression equations have been developed, similar to those used by Hagstrum & Miliken (1988). The equation developed by Evans (1983) has been used for *S. oryzae*, in order to include the dependence on temperature, humidity and age of insect pests, while for *O. surinamensis*, equation developed by us on the basis of Obretenchev` (1986) data has been used. As far as the dependence of egg laying and death rate have been dependent on the age of elderly imago insects is concerned, the equation developed by Longstaff(1988) has been used for *S. oryzae*. Because of the lack of enough reliable data for *O. surinamensis*, we have accepted that the egg laying has been terminated on the 90th day after the stage of imago of the elderly insects. The time step in the model calculations is 0.1 day.

The simulation has been made for the temperature terms of wheat storage in a flat storehouse and steel bin, with capacities of 2500 and 3000 t, respectively, which have been located in different farms in 2004. The granaries have been filled in during the period June 10th–15th. The initial wheat temperature has been 31–32 °C, and its average moisture content of 12,8 %. During its storage, we have measured its temperature from time to time, in different spots of both layers from the grain bulk, at a distance of 0.5 and 2 meters from the surface, by using an electronic thermal probe with an accuracy of 0.2 °C. The points have been nine (one in the center and by four at a distance of 0,7 and 4,5 m from the wall) in the steel bin, and 15 (by three on the ridge, the two slopes and by the walls) in the flat storehouses.

In order to determine simulation models validity we have used infestation change data, determined according to the main method for taking samples by using cylindrical probe (one meter in length and 0.5 kg in capacity) from five points in the steel bin (one in the center and by four on the semi-radius) and nine in the flat stores (three on the embankment ridge and the remaining between the ridge and the walls). The insect pests have been separated by sieving the samples and their number has been calculated to one kilogram. Moisture content has been determined on the same samples, as well.

The wheat stored has been cooled down by ventilation with atmospheric air during the night hours of the day (22–6 hours), with the exception of the days with relative humidity of air above 90 % for the steel bins and above 70 % for the flat storehouses.

We have used MS Excel 95 Program to do the simulation and models validity determination.

Results and Discussion

Monitoring of grain temperature

The temperature change of the upper two-meters layer of the grain embankment in the flat storehouse and the steel bin has been shown on Fig. 1.This layer has been chosen for observation because it has been the last one to be cooled down during ventilation and it usually has the highest rate of infestation. Because of the starting ventilation, grain temperature begins to decrease together with the filling up of the granaries, and after approximately 20 days, from 31–32 °C it has reached as low as 26 °C. After this period, the temperature in the flat storehouse continues to decrease, by the same rate approximately, while in the steel bins it has been arrested within the limits of 27–28 °C, about 50 days more, up to the beginning of the autumn temperature decrease of the atmospheric air (the mid of September). The reasons for the slower cooling down of the grain in the steel bin are: the less specific airflow rate during ventilation (10 m^3/h x t) and the higher airflow heating in the fan (4 °C). Because of this, in the steel bins, there are optimum temperatures for insect population growth for about 70 days from the beginning of storage, while in the flat storehouses, because of the quick cooling down, it is only 20 days. During the continuing temperature decrease up to the protective values (18–19 °C) the insect population growth also continues, although with lower intensity. These temperatures can be reached after 85 days (the end of September) and after 135 days (the second half of November) from the beginning of the storage, in the flat storehouse and the steel bin, respectively. During the storage, wheat moisture content has been changing within small limits (± 0.5 %).

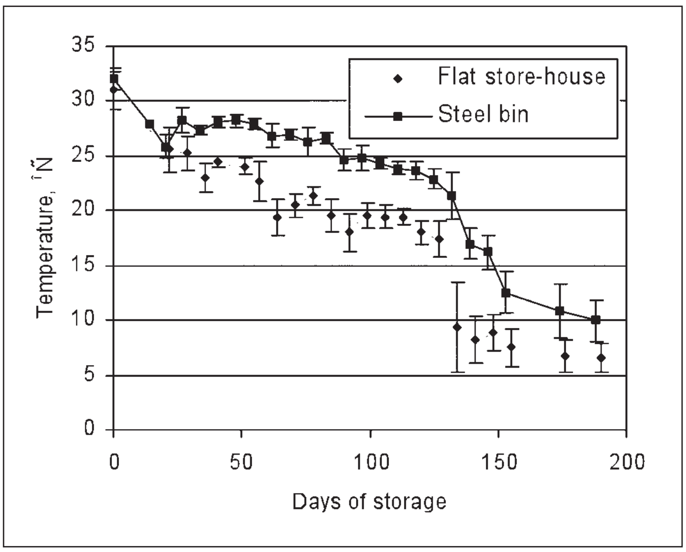

Fig. 1. Temperature change of the two-meter upper layer of freshly gathered wheat, stored in a flat storehouse and in a steel bin.

Simulation of insect population growth

At temperature conditions, in both granaries, we have made simulation of insect population growth of *S. oryzae* and *O. surinamensis*. Grain moisture content during simulation has been accepted as 13 %, because the specified limits of its change do not have any effect upon its increase. Besides that, these are the limits of humidity (12–13 %), at which the wheat is most often stored. The insect population growth of one pair of both insect pests in the steel bin has been shown on Fig. 2. During the first 33 and 23 day of wheat storage, the number of *S. oryzae* and *O. surinamensis* has not been changed. During this period, as a result of their immigration from the environment, its insignificant increase is also possible. During the next days, a quick increase in population number can be observed, because it is the beginning of imago stage of the adult insect pests from the first generation of pests out of the initial infestation. The ten day earlier beginning of *O. surinamensis* number increase is due to the shorter development time at temperatures of 27–32 °C. During the period from 50th to 90th day, the number increase of insect pests from both species has approximately one and the same speed. When their numbers have been equalized on 90th day, the increase has continued up to 145th day (the beginning of December). The increase in *S. oryzae* number is quicker and the maximum value reached is 3.6 times greater, because of which this species has a higher risk for the stored grain.

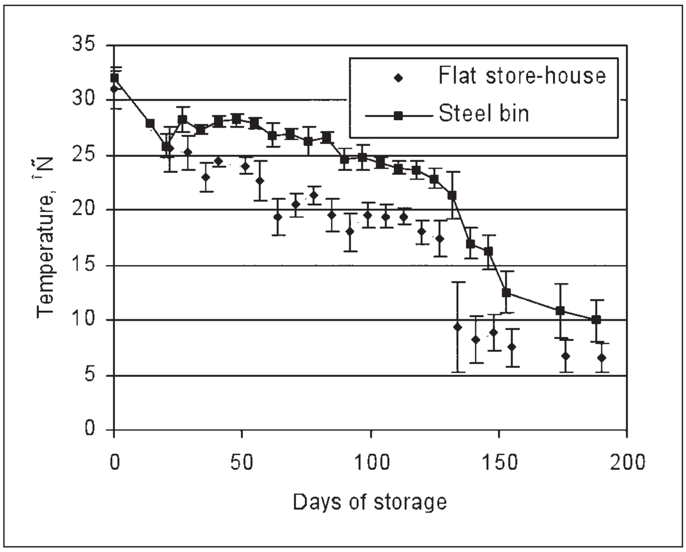

Fig. 2. Predicted number increase of a pair of *Oryzaephilus surinamensis* and *Sitophilus oryzae*, when storing wheat in a steel bin.

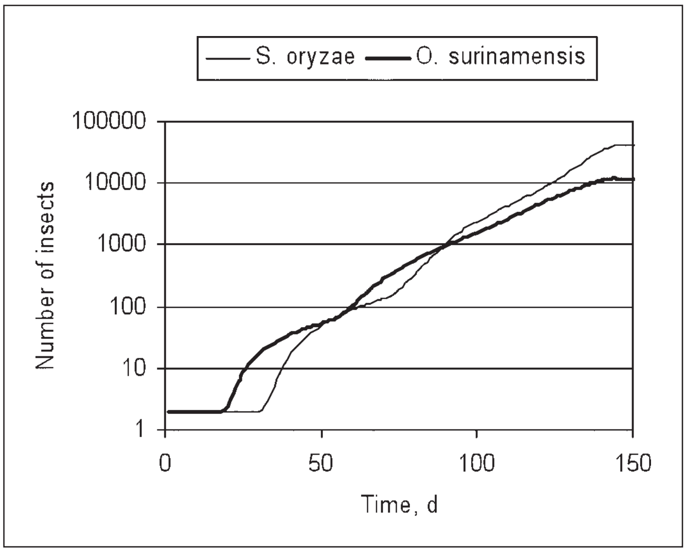

Fig. 3. Predicted number increase of a pair of *Oryzaephilus surinamensis* and *Sitophilus oryzae*, when storing wheat in a flat storehouse.

The insect population growth for both insect pests is analogical in the flat storehouse (Fig. 3). Because of the higher grain temperatures in the initial period of storage (one and the same with those in the steel bin) the growth starts also after 33rd and 23rd day, which has been at one and the same speed for both species during the first ten days. During the next period the growth rate of *O. surinamensis* is slower. The number of both species is equalized during 53rd day, at grain temperature of 24 °C, after which the growth continues up to 95th and 111th day (the midst and the end of October), for *O. surinamensis* and *S. oryzae*, respectively, when their maximum values have been reached, which for the second species are by 4.8 times higher. The latter, in comparison with those in the steel bin are by 80 and 60 times lower for both species, respectively, and can be reached for a shorter period of time of 35 and 50 days.

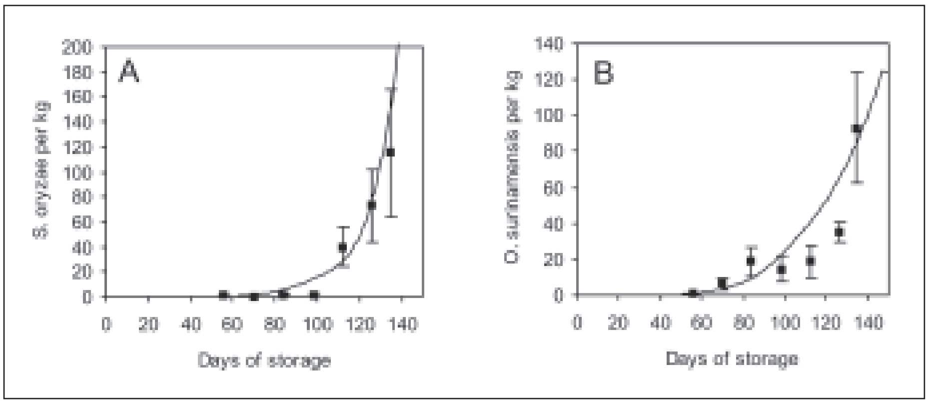

Fig. 4. Measured (in dots) and predicted (in lines) infestation density of *Sitophilus oryzae* (A) and *Oryzaephilus surinamensis* (B) in a steel bin.

Validity of simulation models

Validity has been determined by linear regression dependence analysis between the infestation values of both species of insect pests, obtained during the periodical measurements in both granaries and those determined after the model (Fig. 4 and 5). It can be seen from the figures that the simulation results reflect comparatively better infestation change rate of the stored wheat in the steel bin. This can be confirmed also from the statistical results obtained (Table 1). The values of the actual density (y) calculated after the regression equation ($y = ax + b$) from the predicted value after the model (x) reflect 95 and 79 % and 78 and 85 %, respectively of insect population density change rate of *S. oryzae* and *O. surinamensis* in the steel bin and in the flat storehouse. The differences are due to the different grain temperatures in both granaries on one side and the different thermophilicity of both insect pests on the other side. In all cases studied, “*a*” coefficients are indiscernible from 1, while “*b*” coefficients – from 0, which is an indication for the good juxtaposing between the prediction after the model and the determined in practice insect population growth. This means that the simulation models can be used with sufficient for the practice accuracy when determining insect population growth increase in storing freshly harvested wheat. The real results obtained have confirmed (by a few days difference) the predicted terms of population growth, as well, after which a slow decrease has been observed. The relations between the maximum values of infestation reached in both granaries 46 and 133 times, respectively for *S. oryzae* and *O. surinamensis* are similar. In the steel bins, as well as in the flat storehouses,

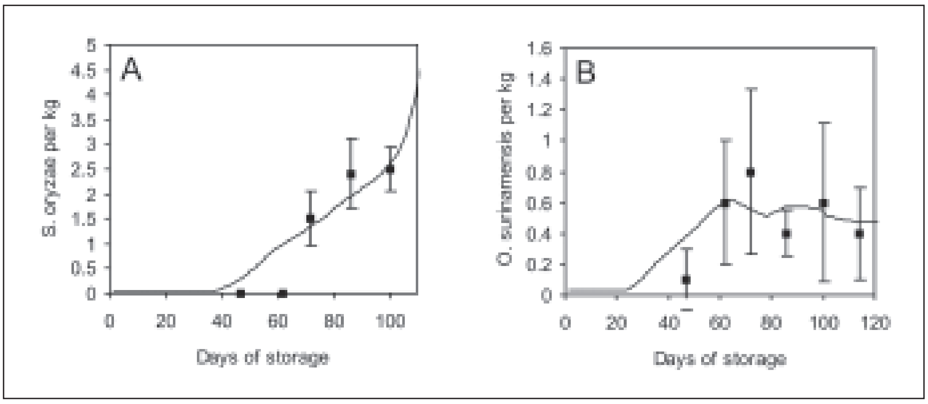

Fig. 5. Measured (in dots) and predicted (in lines) infestation density of *Sitophilus oryzae* (A) and *Oryzaephilus surinamensis* (B) in a flat storehouse.

Table 1. Regression parameters of measured (y) against predicted population densities of *Sitophilus oryzae* and *Oryzaephilus surinamensis.*

Parameters	Steel bin	Flat store-house		
	S. oryzae	*O. surinamensis*	*S. oryzae*	*O.surinamensis*
n	6	7	5	6
Slope(a) ± SE	1.15 ± 0.13	0.91 ± 0.22	1.31 ± 0.32	1.23 ± 0.37
t (H_0: a = 1)	1.14	0.42	0.95	0.63
P	0.32	0.69	0.41	0.56
Intersept(b) ± SE	−0.47 ± 7.58	7.96 ± 8.52	−0.60 ± 0.52	−0.12 ± 0.19
t (H_0: b = 0)	−0.06	0.93	0.20	−1.15
P	0.95	0.39	0.85	0.33
r^2	0.95	0.78	0.79	0.85

the increase of *S. surinamensis* is 1.2 and 3.6 times greater. The differences with the simulation results are due to the different rate of initial infestation.

Conclusion

From the simulation results obtained it follows that the grain stored in flat storehouses, when cooled down by atmospheric air has been protected from insect pests to a greater degree. The reason for this has been the slower insect population increase and the shorter time, during which the grain has been exposed to the impact of insect pests. Because of that, in well carried out good sanitation measures, before harvesting the new crop grain, in the storehouses themselves and on the territory of the whole granary (basic cleaning, pesticides treatment, keeping to the sanitary and hygienic measures), as well, fumigation during storage can be escaped.

When storing grain in steel bins with great capacity, the grain has been exposed a longer time to insect pests impact because of the slower cooling down. This has imposed fumigation at the beginning of September, when insect population has been increasing quickly and temperature decrease is going to follow. In order to carry out efficient control measures against pests, infestation monitoring should be held, as well. Having in mind the simulation results and the sensitivity of the basic method for infestation density determination (by means of taking samples), the latter should start not earlier than 40 – 50 days after filling in the storehouses with freshly harvested grain. The measures undertaken should be directed mainly towards *S. oryzae* which is of greater hazard for the stored grain, because of the quicker insect population growth.

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