Bulgarian Journal of Agricultural Science, 14 (No 6) 2008, 528-534
Agricultural Academy

A HEATED TRAP FOR DETECTING INSECT INFESTATION IN STORED GRAIN AT LOW TEMPERATURES

D. K. KUZMANOV*, N. D. DIMITROV, N. P. GINOV and I. G. YANCHEV
University of Food Technologies, BG - 4002 Plovdiv, Bulgaria

Abstract

KUZMANOV, D. K., N. D. DIMITROV, N. P. GINOV and I. G. YANCHEV, 2008. A heated trap for detecting insect infestation in stored grain at low temperatures. *Bulg. J. Agric. Sci.,* 14: 528-534

In detecting insects and monitoring of infestation in cooled down grain storage, trap sensitivity has been decreased. In order to avoid this problem a trap with a built-in heater has been developed. The heater increases the temperature in the trap up to the optimum one for insects trapping. The appropriate heater power (2.1 W) to keep up the temperature of the trap at 33°C has been determined at laboratory conditions. An outer controller has been used to keep up a constant temperature. Two couples of traps have been used – heated traps and unheated traps, which have been investigated in a flat storehouse and in a metal silo cell filled with wheat with a temperature of 8 – 19 °C. It has been established that the detection frequency of rice weevil *Sitophilus oryzae* (L) and sawtoothed grain beetle *Oryzaephilus surinamensis* (L.) by using the heated trap has increased by 30 and 80 %, respectively. The number of insects of *O. surinamensis* trapped by using the heated trap has been significantly higher by 3.2 times while the difference between the numbers of *S. oryzae* insects trapped by using both traps has been insignificant. As regards the method of taking samples, the frequency of insect detection by using heated trap has been by 60% greater. Thanks to the increased sensitivity of the heated trap it is now possible not only to detect insects in stored grain during its cooling down but also to follow the insect infestation variation.

Key words: traps, heater, *O. surinamensis, S. oryzae,* metal silo bin, flat, storehouse

Introduction

The on time detection and tracing insect infestation variations in stored grain are necessary in order to undertake the most suitable methods and means for insect control. The basic method for detecting and determining of an open form of insect infestation consists of taking samples from the grain bulk and their analysis at laboratory conditions. This method is characterized by a number of disadvantages (great labor-consumption, low sensitivity etc.), which impose its improvement. For that purpose, at the end of the 60ies of the last century the first trap for insect infestation detection of stored grain has been designed (Loschiavo and Atkinson, 1973). Later on several constructions have been developed, which have become the object of investigation by a number of authors. It has been established that many factors influence upon the efficiency of traps usage, grain temperature being the main one. By decreasing the temperature from 32°C to 5°C the number of insects trapped from the various species has decreased by 4 to 9 times (Barak and Harein,

e-mail: kuzmanow.dim@abv.bg

1982; Fargo et al., 1989; Reed et al., 1991; Vela-Coiffier et al., 1997; Hagstrum et al., 1998; Arbogast et al., 2004). In order to compensate this decrease it has been proposed to increase the trap delay time in the grain mass up to 14 days at low grain temperatures. Another decision is to increase the temperature of the perforated part of traps up to the optimum one for insect development by mounting a heater (Zakladnoj, 1979). Investigations in this field have not been made and this idea has not been really implemented.

By this study we have set the aim to design and construct a trap with an electric heater, to determine its required power and to compare its efficiency with the unheated one at production conditions, stored grain temperatures within the temperature range of 8 – 19°C.

Materials and Methods

The heated trap constructed (Figure 1) differs from the already known ones by its greater diameter (ϕ 50 mm) and by replacing the perforated cylinder by a cylinder, constructed from a metal sieve with elongated openings having dimensions of 1.5/20 mm. Along the axis of the trapping part of the cylinder a standard electric heater with resistance of approximately 500 Ω has been mounted. An aluminum screen has been mounted between the heater and the perforated cylinder, which ensures an even distribution of heat along the length of the trap. A similar unheated trap has been used as a control. The power required by the heater has been determined at the laboratory conditions using an insulated vessel (0.7 x 0.7 x 0.7m) filled with wheat at 2-4, 7-9, 13-15 and 15-17 ^{0}C. The investigations have been carried out at heater power of 1.0, 1.5 and 2.3 W, achieved by varying the supply power within the range of 22 – 32 V, by using an autotransformer. The temperatures on the screen, on the perforated surface of the trap and of the grain have been measured by using sensors and their values have been registered by means of a 3-channel vertical face chart recorder TGL 722, probe 100 Ω Pt RTD, range 0-60°C, precision class of 0.35/0.1. In order to keep up a constant temperature in the

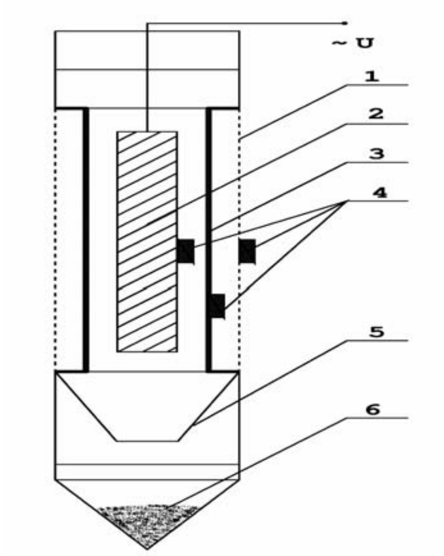

Fig. 1. A heated trap for insect's detection: 1 – metal sieve cylinder; 2 – heater; 3 – aluminum screen; 4 – temperature sensors; 5 – shield; 6 – food bait

trap independent on that of the grain, an automatic control system has been used by means of an outer microprocessor controller and a temperature sensor (Pt 100) mounted on the screen.

Two couples of traps – the heated and unheated traps have been investigated in a flat storage (3200 t capacity) filled in with wheat, in March and April 2003 and in a steel bin (3000 t capacity) from November 2003 to June 2004, each filled with wheat. In both cases, the trap screen temperature has been kept up within the range of 31 – 34 ^{0}C. The traps have been placed every 4 days in different points along one-half of the bin radius (4.5 m) and along the bulk ridge of the flat storehouse, at a distance of 2 m.

The traps have been placed in the grain at a depth of 0.2 m from the surface. Chopped wheat with moisture content of 15-16 % has been used as food bait. The traps delay time in the grain bulk has been 4 days. Parallel to this, we have determined also the insect population density in samples taken by a cylindrical probe (1 m in length and 0.5 kg in capacity) around each trap (4 probes at a distance of 1 m and 1 in the middle). The samples around every trap have been collected in a total sample. This sample has been sieved and the insects - determined and counted.

The initial infestation rate at the beginning of the investigations in the steel bin has been 4±1.1 insects per kg for *O. surinamensis* and 3.8±0.8 insects per kg for *S. oryzae*, and in the flat storehouse – 1.2±0.8 and 0.8±0.3 insects per kg, respectively.

The grain bulk temperature has been measured periodically every 15 days at different points of two layers of the grain bulk, at a distance of 0.5 and 2 m from the surface, by using an electronic thermal probe, with accuracy of 0.2°C. The points in the steel bin have been 9 (1 in the center and by 4 at a distance of 0.7 and 4.5 m from the wall), and in the flat storehouse – 15 (by 3 every 5 m along the ridge, the two slopes and at the walls). Besides that, periodically, before taking out the traps, the grain temperature has been measured at a distance of 5, 40, 60, 80 and 100 cm from each heated trap.

The initial grain temperature in the steel bin and in the flat storehouse has been 19 and 8°C, respectively.

The statistical processing of results from investigating the heated trap has been done by using Statgraphics 5.0 program. The significance of the mean number difference between the insects trapped by both traps has been determined consecutively by F- and t-tests.

Results

Heater Power

By increasing the power of the heater mounted in the trap from 1 to 2.3 W and of the grain temperature from 2.5°C to 17°C, the screen temperature increases within the range of 18°C to 40°C (Figure 2). On the basis of the experimental data obtained, a correlation equation has been worked out describing the screen temperature dependence on the grain temperature and the heater power in the variation ranges studied (r^2 = 0.91 and SE = 2.12°C):

$$t_{screen} = 7.1351 + 10.4648.P + 0.6863.t_{grain}$$

where: t_{screen} is the screen temperature, °C;

P is the heater power, W;

t_{grain} is the grain temperature, °C.

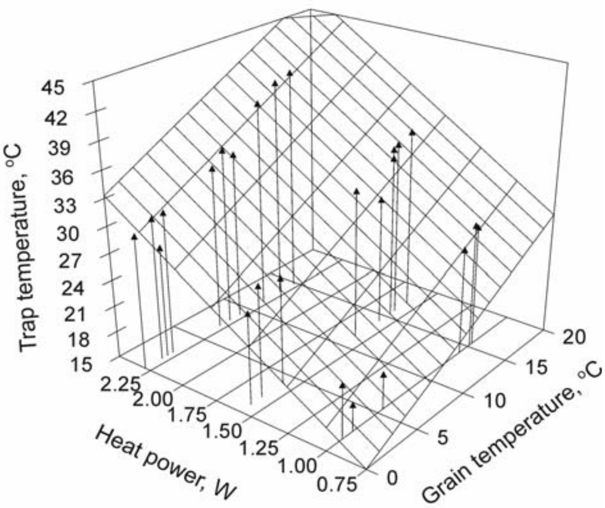

Fig. 2. Temperature of the trap screen at different heater power and grain temperatures

Because the equation coefficients are statistically significant at confidence level of $\alpha = 0.05$, both factors – the grain temperature and the heater power have an effect upon the trap screen temperature the effect of the second one being many times greater. The keeping up of a constant trap temperature, regardless of the grain temperature is possible by using an automatic control system based on a suitable controller. The minimum heater power – 2.14 W in this variant has been calculated using the equation for obtaining the screen temperature of 33°C – the upper limit of the optimum one for insect's development, at minimum grain temperature of 5°C. At these conditions the fluctuating temperature mode of the screen controlled by a bi-positional controller, has have amplitude of about 1°C (Figure 3). The trap surface temperature has been by about 7°C lower than the mean value of the screen. The temperature has been without visible fluctuations and it has reached the set value 500 – 600 min after switching on the system. The grain temperature in the vessel, at a distance of 5 cm from the trap surface, has increased by about 6°C.

Grain Temperature

During production investigations the mean grain temperature in the bin at the beginning of the experi-

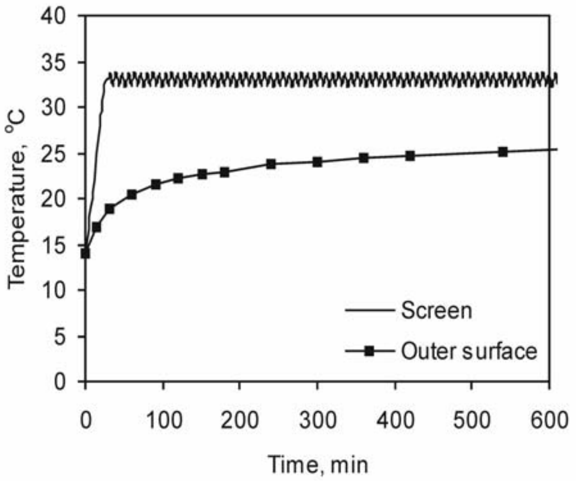

Fig. 3. Temperature variation of the screen and surface of the heated trap at 14.5 °C temperature of grain

ment (November 19, 2004) has been 19°C (SD=0.9) and has been decreasing constantly up to approximately the 35th day when it has reached 8°C (SD=0.8). Thus value has been preserved till the end of April and then increased to 16^{0}C till the beginning of June. Grain temperature in the flat storehouse has been within 10 to 12єC during the period investigated.

The temperature of the grain layer at a distance of 5 cm from the heated trap in both grain storehouses has been about 20^{0}C. The trap has created a temperature field with radius of 1 m around it.

Monitoring of Insect Infestation

During the period investigated, insect infestation consisted of the two most widespread species in R Bulgaria – the sawtoothed grain beetle *Oryzaephilus surinamensis* (L.) and the rice weevil *Sitophilus oryzae* (L.). The variation rate of insects trapped by both traps has been similar to grain temperature variation (Figure 4). The number of *O. surinamensis* and *S. oryzae* trapped has been preserved in approximately similar limits in the bin from the middle of December till the end of January, respectively, after which it has decreased sharply because of the grain cooling down to 15°C. The decrease has continued till the end of January and the middle of December, respectively for the two insects, when grain temperature has decreased permanently up to 8°C. The mean number of *O. surinamensis* caught by heated trap during the storage is significantly (t Stat=3.106, P=0.0017, df=44) greater (3.2 times) as compared to the unheated trap. The difference has been kept (statistically significant) as during the first period, at grain temperature within the temperature range of 10 – 19°C (t Stat =15.32, P<0.001, df=6) – 3.8 times so as during the next one with lower temperature (t Stat =4.23, P < 0.001, df=38) – 3.2 times.

The difference between the mean numbers of *S. oryzae* (t Stat =0.47, P=0.33, df=7) trapped by both types of traps has been insignificant. Besides that, by using the heated trap a considerably smaller number (6.3 times) of *S. oryzae* (t Stat =12.46, P<0.001, df=7) has been trapped in comparison with *O. surinamensis*, regardless of the approximately identical populations density.

A similar course has been observed in infestation change also, taken by the method of taking samples around the traps. During the initial period, at grain temperatures within 10 and 19^{0}C the mean population density of both species have been 3.2 insects per kg (SD=2.5). Later, when grain temperature has decreased below 10^{0}C, the infestation by *O. surinamensis* has remained constant at 0.7 ± 0.38 insects per kg. *S. oryzae*, however, has not been detected after the middle of December, though it is more tolerant to low temperatures. The ratio of the mean number of *O. surinamensis* trapped over the entire investigation period to the mean number per 1 kg sample of grain has been 12.4:1 for the heated trap and 3.9:1 for the unheated trap, i.e. a 3.2 times difference. The difference in ratios for *S. oryzae* has been smaller – 1.2 times.

Frequency of Insect Detection

The detection frequency of pests, representing the ratio between the number of observations, in which pests have been detected and the total number of observations expressed in percentage has been an index for traps efficiency. During the total period of grain storage in the steel bin, the frequency of detec-

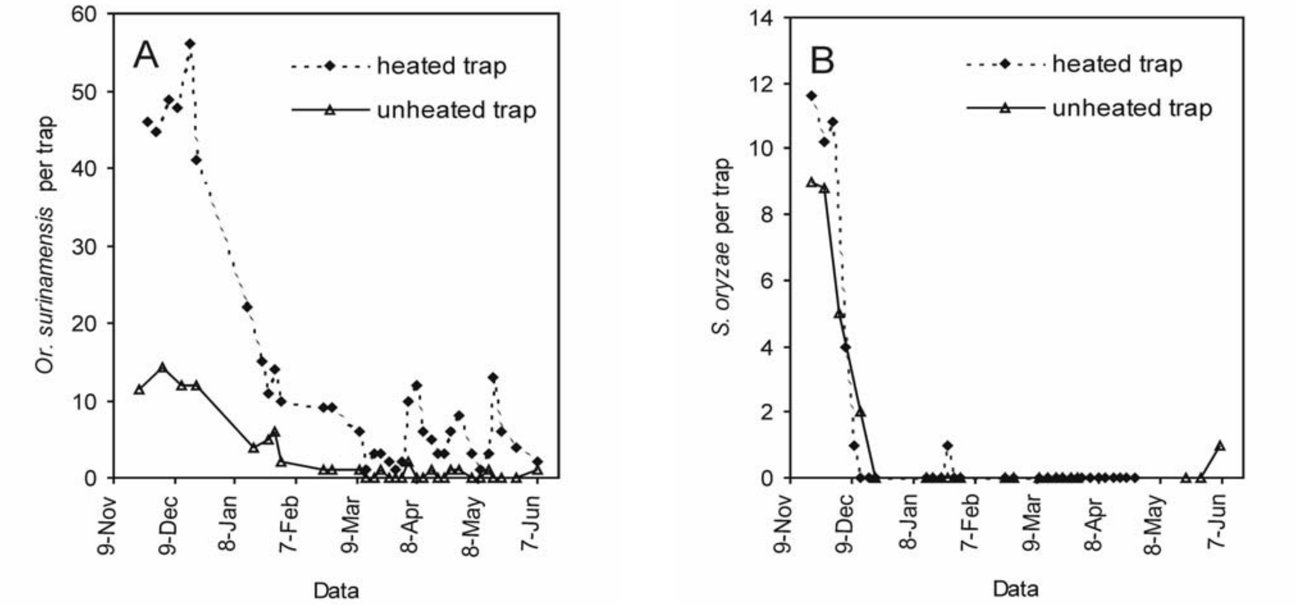

Fig. 4. Mean number of insect's trapped *O. surinamensis* and *S. oryzae* (insects per 4 days) by using the heated trap and the unheated trap during wheat storage in a steel bin

tion of *O. surinamensis* by means of heated trap has been 100%, and by unheated trap – 51%. During the same period, the other species - *O. oryzae* has stood out by a comparatively smaller frequency of 15% and 11.5%, because of the lack of infestation during the greater part of the investigation period. The ratios between the detection frequency of *O. surinamensis* and *S. oryzae* by both traps (heated and unheated ones) in the steel bin have been 1.96 and 1.3, respectively.

Up to grain temperature decrease of 10°C the ratio between the detection frequency of both species (heated: unheated and heated: taking of samples) has been within the range of 1.55: 1 – 1.62: 1. During the next period by using the heated trap *O. surinamensis* can be detected by frequency of 100 %, while by the unheated trap and in the samples taken, by 44 % and 48 %, respectively, i.e. the difference is 2 times greater.

The ratio between the frequencies of detection of both species by using the traps has been analogical to the above stated in the flat storehouse. Besides this, by using the heated traps some other insects have been detected, as well (*Rhyzoperta dominica* (F.), *Tribolium castaneum* (Herbst) and *Tyroglyphus farinae* (L.), which have not been detected by the unheated trap and in the samples taken.

Discussion

The temperature of freshly harvested grain (wheat and barley) in July has fluctuated between 30°C and 34°C. During storage in flat storehouses and in steel bins with capacity of 2500 – 3000 t, the temperature of grain has been preserved within the optimal range for insects development (27 – 35°C), respectively, up to the middle of August and September, although its cooling down by ambient air ventilation. Having in mind that grain insect infestation starts early during the first days of grain storage (Vella-Coiffier et al., 1997; Hagstrum et al., 1998) 1-2 generations have been developed during this period. The cooling down up to protective temperatures (below 21°C) can be reached towards the end of September and November, respectively, in the flat storehouses and in the bins.

During the initial period of their storage the insects have been detected by traps earlier and with higher frequency as compared to the method of taking samples. At grain cooling down from 23 to 14°C, however, the traps efficiency determined by means of the ratio between the number of insects trapped and those detected in 0.5 kg of samples has decreased by 4 and 5 times, and at temperatures lower than 14°C – by 60 and 12.8 times, for *Cr. ferrugineus* and *R. dominica*, respectively (Hagstrum et al., 1998). Reed et al. (1991) have determined that in January the trap efficiency has been decreased by 3.5 times for all insects detected. These results have been confirmed later on by Athanassiou et al. (2001).

The investigations of temperature effect upon the number of insects trapped have been carried out in Russia (Saulkin, 1979). The efficiency decrease of traps at lower temperatures has pushed the authors to increase traps sensitivity by using insects' ability to migrate in the grain mass when heat source has been available (Zakladnoj, 1979). In the capacity of such, they have proposed an electric heater, mounted in the inner part of the trap. As the results from our preliminary experiments have shown, the proposed temperature increase up to 40°C possesses a repulsive effect on population and sensitivity increase cannot be achieved, the result might be rather negative. In our investigations we have accepted the temperature in the inner part of the trap to be close to the upper limit of the optimum one for development of most insects – 33°C. We have also found that when the heater is under operation the temperature field along the length of the trap has been unevenly distributed in time and space. For its leveling in space we have mounted an aluminum cylinder between the heater and the sieve surface, which has served as a screen for the higher temperatures of the heater and levels the heat stream to trap periphery. The trap temperature increase by using a heater, as the authors have suggested, would have lead also to difficulties in coordinating its power at different temperature conditions in the grain bulk. Because of this, the maximum heater power of 1.5 W has been calculated according to the analytical dependence established. At this power the trap temperature could not be increased above 33°C, at grain temperature of 17°C. At this power, which can be reached at safe power supply below 36 V and grain temperature from 5°C to 17°C, the screen temperature will be fluctuating between 26°C and 33°C. In order to be able to keep up the trap temperature within the limits desired, regardless of grain temperature, an automatic system has been developed, during the operation of which the temperature fluctuation amplitude does not surpass 1°C.

Under the effect of heat emitted from the heater in the grain bulk, a temperature gradient has been created, which has been the reason for insects migration directed towards the trap. The temperature gradient has been at a distance of 1 m from the trap.

The frequency of detection of *S. oryzae* increases at a lower degree – 1.3 times, at one and the same number of insects trapped, which is a confirmation of the results obtained by Fargo et al. (1989), according to which the temperature does not have any effect upon the trapping of insects from this species. Because of the different temperature effect and the smaller mobility, at the lower temperatures *S. oryzae* cannot be trapped by using traps, although a certain time after their decrease below 10°C in the samples taken from the same section, 0.5 ± 0.1insects/1 kg each has been detected. Similar results have been obtained by Reed et al. (1991) for the insects *R. dominica, Oryzaephilus spp.* and *Cryptolestes spp.*

Conclusions

A trap with a built-in heater has been created, having 2.1 W powers for increasing of temperature up to the optimum one for trapping - 30-33°C. By using heated traps, at grain storage temperature of 8-17°C pests *O. surinamensis* and *S. oryzae* can be detected by a higher frequency than by using the common type unheated traps (80 and 30%, respectively) and the basic method for determination of insect infestation rate by taking samples (60%). Because of the similarity of insect infestation density and the number of insects trapped, by using the heated trap it is possible not only to detect them in the grain bulk during cooling down but also to follow the course of insect infestation variation during the storage period.

References

Athanassiou, C. G. and C. T. Buchelos, 2001. Detection of stored-wheat beetle species and estimation of population density using unbaited probe traps and grain trier samples. *Entomologia Experimentalis of Aplicata*, **98**: 67-78.

Arbogast, R. T., D. K. Weaver, P. E. Kendra and Sh. R. Chini, 2004. Temperature variation in stored maize and its effect on capture of beetles in grain probe traps. *J. Stored Prod. Res.,* **40** (2): 135-150.

Barak, A. V. and P. K. Harein, 1982. Trap detection of stored grain insects in farm-stored shelled corn. *J. Econ. Entomol.,* **75**: 108-111.

Fargo, W. S., D. Epperty, G. W. Cuperus, B. C. Clary and R. Noyes, 1989. Effect of temperature and duration of trapping on four stored-grain insect species. *J. Econ. Entomol.,* **82**: 970-973.

Hagstrum, D. W., P. W. Flinn and Bh. Subramanjam, 1998. Predicting insect density from probe trap catch in farm-stored wheat. *J. Stored Prod. Res.,* **34** (4): 251-262.

Loschiavo, S. R. and J. M. Atkinson, 1973. A improved trap to detect beetles (Coleoptera) in stored grain. *Can. Entomol*., **105**: 437-440

Reed, C. R., V. F. Writch, T. W. Maize, J. R. Pedersen and J. Evans, 1991. Pitfall traps and grain samples as indicators of insects in farm-stored wheat. *J. Econ. Entomol.,* **84** (4): 1381–1387.

Saulkin, V. I., 1979. Investigation of distribution and migration objective laws of the main bread reserves in the grain bulk during storage. PhD thesis, Moscow (Ru).

Vela-Coiffier, E. L, W. S. Fargo, E. L. Bonjour, G. W. Cuperus and D. W. Warde, 1997. Immigration of insects into on-farm stored wheat and relationship among trapping methods. *J. Stored Prod. Res.,* **33** (2): 157-166.

Zakladnoj, G. A., V. I. Saulkin and N. M. Karpenko, 1979. A trap for establishing grain insect infestation. Author‘s certificate N 67175, Russia (Ru).

Received September, 2, 2008; accepted for printing November, 2, 2008.