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Characteristic of Fumigation Test on Stored – grain Insects in the Northeast Area of China

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Abstract: In this paper, the condition of geography and climate, main stored – grain species and stored – grain insects, the type of the warehouse, the fumigation equipment and medicine, and the main way of prevention and cure for stored – grain insects in the northeast area were briefly introduced. The results and characteristic of the typical field fumigation test in this area were analyzed in details. The fumigation field test includes phosphine recirculation and AlP deliquescence fumigation test in shallow silo, and AlP deliquescence fumigation test in large warehouse.

Key words: phosphine, AlP, fumigation

1 The Condition of Stored Grain in the North East of China

1.1 The Condition of Geography and Climate

The northeast area lies in the northeast part of China, which includes Liaoning, Jilin and Heilongjiang provinces. This region is situated between 120° – 135° east longitude and 40° ~ 50° northern latitude, which belongs to the cold and wet ecosystem area in the northeast Chinese stored-grain regions. Its climatic characteristic is that air temperature varies in great extent in spring and autumn. Sometimes the change exceeds 10℃ each time. In summer, it is very hot in this area with a long sunshine time and plentiful precipitation. The average air temperature is above 15℃. In winter, it is freezing in this area with a short sunshine time. The average air temperature is below 0℃.

1.2 The Main Grain Species and Stored-gain Insects

The grain species mainly includes corn (maize), paddy rice, wheat, and soybean in this area. The stored-grain insects mainly include Sitophilus zeamais, Tribolium castaneum, Ttibolium confusum, Sitotroga cerealella, Plodia interpunctella. Among these insects, the most serious insect pest are Sitophilus zeamais, Tribolium castaneum, Plodia interpunctella. The active time of stored-grain insects is between July and October every year. After October stored – grain insects get into winterization or incubation status.

1.3 the Main Type of Warehouse, Fumigation Equipment and Tablets

The main type of warehouse is shallow (short) silos, and large warehouses. The fumigation equipment mainly includes recirculation fan, recirculation pipe, ventilation pipe, fumigant gas concentration testing tube, phosphine generator, and phosphine concentration tester. The gas recirculation fans are divided into both the fixed and the movable type. The ventilation pipe is fixed. The ventilated passage is built underfloor or on the floor of the storage. The fumigation materials mainly include AlP tablets, chloropicrin and dichlovos. The residual pesticide protection chemicals mainly include Malathion and diatomite.

1.4 The Main Prevention Type of Stored – grain Insects

The main type of prevention and cure for stored – grain insects is by adding phosphine fumigant to the storage, then using the phosphine recirculation fumigation through the ventilation pipe, and by natural gravity phosphine fumigation by laying phosphine tablets and plates on the grain floor or in aeration ducts under the grain floor.

2 The Characteristic of Phosphine Fumigation Test

2.1 Recirculation Fumigation Test in a Shallow Silo

2.1.1 the material

The No. 3 shallow silo of Fuxin Xihe State Grain Depot was selected as a test silo. The capacity of the silo is 11 540 m^3 with 30 m in diameter, 14.5 m in eaves height, and 21 m in total height. In this silo, 7 173 tons of corn was stored with a moisture of 13.5%, a impurity of 0.5%, and temperature between 15℃ and

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25℃. Stored-grain insects include 3 Tineidaes per square meter, 1 Tribolium madens per kilogram, 1 Sitophilus zeamais per kilogram, 10 Troctes divinatorius Muller per kilogram. 56% AlP tablets are used as the fumigant. The recirculation fumigation system is fixed, and the phosphine generator is movable. The measure range of phosphine concentration tester is 0 – 500 ppm, with an accuracy of 1 ppm. The radial ventilated passage is underground.

2.1.2 the method

There are 6 gas sampling tubes in the silo; 5 of the tubes were placed at a depth of 0.3 – 1 m under the grain surface, each being placed in the east, west, south, north and center area. The last one was suspended within the silo to sample headspace gas. Copper mechanical components, instruments, electrical wires and switches were protected by grease coating or sheet plastic covering. The entrance of temperature-testing cable, natural ventilation, mechanical ventilation, entrance of person and large doors were sealed with plastic, gluey paper and glue. An airtight gate was placed over the inlet of the axial flow ventilator and intake of grain were sealed. Recirculation ventilation was done in the silo for 10 minutes to test for leaks, then the place of leaks was checked, and was sealed. According to the user manual of phosphine generator, 16.5 kg AlP and 20 bottles of carbon dioxide gas (25 kg per bottle) was transferred into the silo. Recirculation ventilation was done in the silo, starting within an hour of dosage and was operated during the first two days. The concentration of phosphine in the silo was measured everyday at 9:00 a. m. and 15:00 p. m., respectively, and the results was recorded in details. Recirculation fumigation was carried out for 14 days, followed by natural ventilation for 14 days. The fumigation effect was examined when the concentration of phosphine was below 0.2 ppm.

2.1.3 the results and analysis

No lived insects were found after the concentration of phosphine in the test silo was maintained above 100 ppm for 8 days. Insect pests weren't found in the storage during the following 4 months.

After the start of the fumigation, the uniform concentration of phosphine must be controlled in the silo by operating the fumigant recirculation fan. The length of time of the first recirculation period is ascertained by the measured curve of gas concentration from the 6 sampling tubes. Usually, the more stored-grain and the smaller the recirculation ventilator air volume, the longer the time of first recirculation is needed. Figure 1 gives the concentration curve of the phosphine in the south and north recirculated pipes after a period of time of the initial fumigation. It can seen that the time of first recirculation should be above 9 hours. The time of first recirculation and the total time of everyday recirculation must be controlled in the lowest level in order to diminish the leak loss because of the local positive pressure in the silo.

Because of better diffusibility using recirculation fumigation, it is considered that the leak of phosphine is one-dimensional, with simple and stable molecular diffusion in one direction when the phosphine fumigation of the certain silo is controlled in a uniform concentration. According to the integral of Fick's law $J = -Ddc/dz$, the concentration in the silo at "n" moment can be inferred, i.e., $C_n = (1-k)n-1C_1$, where C_1 is initial concentration, k is a constant. The value of Cn is decided by the air – tightness of the silo, the quantity of stored-grain, the species of stored – grain, everyday recirculation time and weather condition.

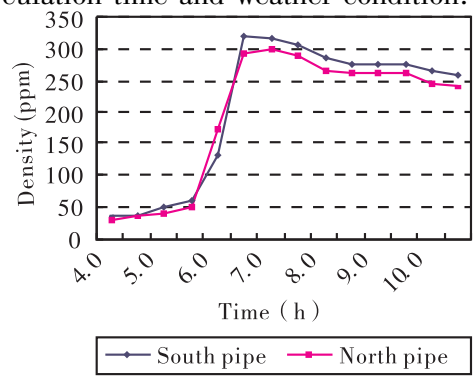

Fig. 1 Phosphine gas concentration in south and north sample pipes

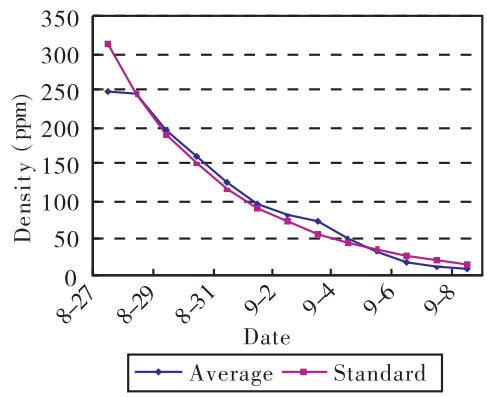

Fig. 2 Recirculation fumigant gas concentration loss rate comparing measured vs calculated rates.

Figure 2 shows the average concentration curve of phosphine and standard function curve

of $C_n = (1-k)^{n-1} C_1$, where $C_1 = 244$ ppm, $C_n = 72$ ppm, $n = 6$, $k = 21.7\%$, that is to say, the concentration of phosphine reduces about 21.7% everyday. It can be seen that the two curves fit well in Figure 2. There exists some deviation when the concentration of phosphine is below 70 ppm, but the actual measured value should be considered as an accurate value. The larger the concentration of phosphine is, the more the moare gas is dissipated in a certain time. Therefore, to minimize total dosage and fumigating by applying only one high concentration of dosage once should be avoided. According to k value of the silo, the concentration of phosphine, and assumed concentration of efficient killing insects, the duration under the concentration of efficient killing insects can be calculated approximatively using the standard function $C_n = (1-k)^{n-1} C^1$.

2.2 AlP Natural Gravoty Fumigation Test in a Shallow Silo

2.2.1 the material

The No. 1 shallow silo of Bayuquan state grain depot was selected as a test silo. The capacity of the silo is 11 540 m^3 with 30 m in diameter, 14.5 m in eaves height, and 21 m in total height. In this silo, 5 700 tons of corn was stored with a moisture of 13.5%, a impurity of 0.5%, and temperature between 1.8℃ and 20.6℃. The height of stored-corn without insects is about 11m. 56% AlP tablets are used as the medicine. The measure range of phosphine concentration tester is 0 – 500 ppm, with an accuracy of 1 ppm. The perforated ventilation ducting is under the silo floor.

2.2.2 the method

The recirculation fumigation method of this silo is the same as the one described in The gas sampling pipes were distributed with one places 1 m above the grain surface, 1 m and 3 m under the grain surface, respectively. Small AlP tablet pockets (pervious cloth bags) were made up outside the silo. According to the pre – arrangement, 8 – 10 persons with respirators came into the silo and probed AlP tablet pockets at depths of 50 – 80 cm under the grain surface through appropriative probe pipe tools. The total quantity of phosphide tablets was 30 kg. 10 kg AlP tablets were put inside 6 entrances of mechanical ventilators at the base of the silo. After the whole silo was obturated (sealed), the place of leak was checked through warning device and then these leak points were sealed. The concentration of phosphine and the temperature of grain were measured everyday. The obturated fumigation lasted for 35 days from 31 May to 6 July. After natural ventilation of 14 days, the fumigation effect can be examined when the concentration of phosphine is below 0.2 ppm by using warning device.

2.2.3 the results and analysis

No lived insects were found when the concentration of phosphine at the place of 3 m under the grain surface and the headspace in the test silo were maintained above 163 ppm for 35 days. Insect pests haven't occurred within 4 months after fumigation, especially undergoing active season for insects.

The concentration of phosphine in the silo headspace reached 105 ppm after 41 hours, which is an efficient fumigation concentration. And the concentration of phosphine at the place of 3 m under the grain surface reached 187 ppm after 17 hours. It has been indicated that velocities of AlP deliquescence and phosphine diffusion in the space are quite fast, and the penetrating ability of phosphine through corn (which is very porous), especially in downward direction, is very strong.

Figure 3 shows the average concentration curve of phosphine and standard function curve of the test silo. It can be seen that the concentration curve of phosphine is divided into two parts. The curve after T days is an attenuation curve of phosphine concentration, which coincides with Fick's law. The concentration of phosphine at "n" moment can be calculated, i.e., $C_n = (1-k)^{n-T} C_T$, where C_T is the concentration of phosphine at "T" moment when AlP gas release comes to end, where k is a constant when the condition of stored – grain is fixed. The curve before T days is an ascending curve of concentration of phosphine. According to the characteristic of phosphine attenuation, when the silo is airtight, the velocity of AlP gas release and the temperature of grain are constants, the concentration of phosphine of "n" moment can be calculated, i.e., $C_n = C_{n-1} + C_w/T - k(C_n + C_{n-1})/2$, where C_w is the concentration of phosphine came from total dosage without loss, k is the loss factor for phosphine concentration. It can be inferred further, i.e., $C_n = C_w/Tk(1 - ((2-k)/(2+k))^n)$, which can be simplified as $C_n = A(1-K^n)$, where A and K are constants. The curves can be drawn by using standard functions, i.e., $C_n = A(1-K^n)$, $C_n = (1-k)^{n-T} C_T$, and the average value of actual testing data. It can be seen that the two curves fit quite well in the Figure 3. However, during the period of AlP gas fumigation, the concentration of phosphine is higher near the

place of probing of the dosage in the silo. So the testing points of phosphine concentration should not be near the points where the phosphine tablets were placed.

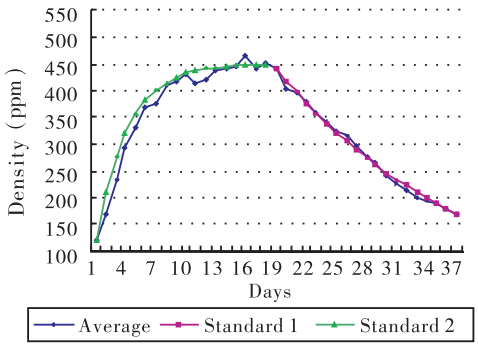

Fig. 3 Gravity phosphine gas concentration loss rate comparing measured vs calculated rates

2.3 AlP Recirculation Deliquescence Fumigation Test In Large Warehouse

2.3.1 the material

The No. 3 large warehouse of Jinzhoujinyang state grain depot was selected as a test warehouse. The capacity of warehouse is 16200 m^3 with 60 m in length, 30 m in width, and 7.88 m in eaves height. In this warehouse 4500 tons of corn was stored with a moisture of 13.5%, a impurity of 1.0%. The height of stored – corn is 4 – 5 m. Stored – grain insects include 13 Tribolium madens and Plodia interpunctella Hubner per kilogram. The ventilation cage passage is on the ground. Recirculation pipe is in a double – side fixed manner. 56% AlP tablets are used as the fumigation dosage. The measure range of phosphine concentration tester is 0 – 500 ppm, with an accuracy of 1 ppm. .

2.3.2 the method

The entrances of cable, mechanical ventilation, axial flow ventilator were sealed with adhesive tape. The doors and windows of the warehouse were sealed with plastic, adhesive tape and rubber strip. There are 8 pipes for testing phosphine concentration in the grain surface. Four pipes were placed in the four corners of the warehouse, the other four were distributed as lines at equal intervals along the center of the warehouse. In the afternoon of 18 September, 28 kg AlP tablets were divided into 6 portions, each of them was wrapped by gauze, put at 6 entrances of mechanical ventilation, and the entrance openings were sealed at once. The first recirculation fumigation lasted for 48 h continuously, then 4 h everyday. The total time of recirculation fumigation was 15 days. The concentration of phosphine in the warehouse was measured everyday. The warehouse remained sealed for 5 days after the recirculation fan was stopped. Natural ventilation was done with doors and windows open in the warehouse the night of 6 October, and then axial flow ventilator was used for 3 days. The concentration of phosphine was measured continually by warning device during the period of ventilation. The prevention staff with respirator began to examine the fumigation effect when the concentration of phosphine is safe.

2.3.3 the results and analysis

Lived insects, the phenomenon of grain fever and dew were not found when the concentration of phosphine in the test warehouse was maintained above 100 ppm for 16 days.

Figure 4 was drawn by using the data recorded at 9:00 a. m. everyday during the period of fumigation. From Figure 4, it can be seen that the concentration of phosphine increases continually after the dosage was added, attains equilibrium after 3 days. Then the concentration of phosphine was maintained between 100 – 160 ppm, which is an effective range where stored – grain insects can be killed. Meanwhile, this range of phosphine concentration has been proved to be favorable to maintain because it is not too high.

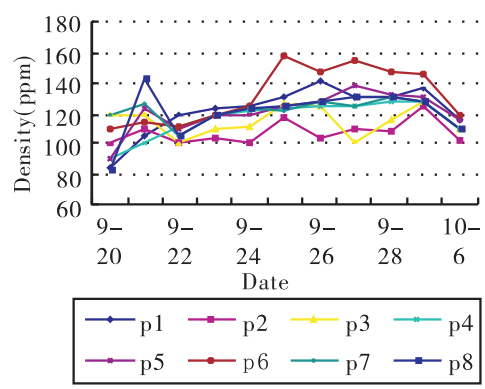

Fig. 4 Fumigation concentration for four corners and centerline of warehouse

The effect of fumigation can be controlled by changing recirculation time everyday and increasing the quantity of medicine. According to the response of grain depot, this method exhibits completed efficacy of fumigation, and it has a merit of simple operation and low cost.

References

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