Fumigation against *Rhyzopertha dominica* by using mixture of CS₂ and CCl₄ – a comprehensive report of a series field trials

Yang Shenghua, Wang Yanan and Xu Xiaozhu

**Abstract**

Phosphine resistance of stored grain insects in China is an urgent problem remaining to be solved for lack of widely acceptable alternatives. As it is being suggested or done by some scientists in reappraising some old fumigants, the authors carried out a series of field trials using a mixture of CS₂ and CCl₄ to disinfest phosphine-resistant strains of *Rhyzopertha dominica* and other common beetles. The results proved that by using the dose rate of 50 - 80g/m³ of the mixture (60% CS₂ and 40% CCl₄ by weight) at temperatures of 14 - 26°C for ten days exposure, a complete kill of common stored grain beetles could be obtained including phosphine resistant strains. The level of residues on the grain was much lower than the standards recommended by FAO and WHO and the cost of fumigation was much lower than using chloropicrin. The mixture might be a transitional alternative to phosphine in some areas of China.

**Materials and Methods**

**Storehouses**

Trials were conducted in small brick-arch, medium-sized brick-arch storehouses and large horizontal grain storage constructed with brick wall and reinforced roof in Sichuan Province.

**Fumigated grains**

Bulk and bagged paddy, wheat and maize were fumigated in the trial. The bulk grain and bag stacks ranged from 3.4 - 4.5m in height.

**Grain temperature and moisture content**

Generally ranged from 14 - 26°C, but with one pile of bulk paddy being heated to 40°C due to heavy infestation of *R. dominica*. The moisture content of paddy, wheat and maize ranged from 12.6 - 13.0%, 13.0 - 13.5% and 13.2 - 13.8% respectively.

**Infested insects**

The dominant species of insect was *R. dominica* (amounted to 50 - 90% of the total population density) and the highest density of it in a particular bulk paddy storehouse amounted to 2000 heads/kg. The other infested species were *Sitophilus zeamais*, *Cryptolestes pusillus*, *Tribolium spp.*, *Oryzaephilus surinamensis* and *mites*. Insect cages were laid at different layers and positions of grain stacks for mortality inspection.

**Method of mixture application**

Applied dose rate ranged around 54 - 81 g/m³ according to the height of grain stacks and the level of insect infestation.
Before application the surface of grain was covered with gunny bags and some bags were hanged up in the upper space of grain for sprinkling fumigant. If the height of bulk grain was lower than 3.5 m or the bagged grain stacks lower than 5 m, all of the fumigant was applied onto the spread and the hanged gunny bags as well as walls and the ceiling. In some cases, some of the total dosage was applied into the grain pile with the aid of preinserted probes.

**Period of exposure**

The exposure time varied from 10 to 48 days in line with the level of insect infestation and the fixed storage period of grain.

**Residues determination**

Grains were sampled from different layers and positions soon after fumigation for residue determination by using chromatographic method by Sichuan Grain Storage Research Institute.

**Results and Discussion**

Table 1 shows the conditions and effectiveness of a series of trials. No survival insects and mites were found in treated grain piles, stacks and test cages soon after fumigation. However, there was only one exception in Huayuan Gran Storage that one alive *R. dominica* was found adult in a test cage. Probably it was caused due to shorter exposure period, yet this grain storage maintained no insects for ten months.

Results have shown that mixed fumigation with CS₂ and CCl₄ under the conditions of dose rate of 50 - 80 g/m³ for more than ten days exposure at temperatures of 14 - 26°C can give complete control of common beetles in stored paddy, wheat and maize.

<table>
<thead>
<tr>
<th>Store</th>
<th>Grain</th>
<th>Quantity (t.)</th>
<th>Moisture content (%)</th>
<th>Dose rate (g/m³)</th>
<th>Temperature (°C)</th>
<th>R. dominica (heads/kg)</th>
<th>Mites (heads/kg)</th>
<th>Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huayuan</td>
<td>paddy</td>
<td>52</td>
<td>13 3</td>
<td>69</td>
<td>16</td>
<td>153</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td>Wangjia-Xiang</td>
<td>paddy</td>
<td>1092</td>
<td>13 2</td>
<td>81</td>
<td>40</td>
<td>301</td>
<td>705</td>
<td>100</td>
</tr>
<tr>
<td>Pengan</td>
<td>paddy</td>
<td>1825</td>
<td>13 0</td>
<td>54</td>
<td>19</td>
<td>33</td>
<td>2</td>
<td>100</td>
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<tr>
<td>Longxi</td>
<td>No 109</td>
<td>paddy</td>
<td>270</td>
<td>12 6</td>
<td>69</td>
<td>22</td>
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<td>18 100</td>
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<td>304</td>
<td>12 8</td>
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<td>26</td>
<td>5</td>
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<td></td>
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<td>wheat</td>
<td>300</td>
<td>12 7</td>
<td>69</td>
<td>21</td>
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<td>304</td>
<td>13 8</td>
<td>69</td>
<td>20</td>
<td>10</td>
<td>10 100</td>
</tr>
</tbody>
</table>

Table 2 shows that the residues of CS₂ and CCl₄ on paddy were much lower than the standard recommended by FAO and WHO (CS₂ 10 mg/kg) and EEC standard (both CS₂ and CCl₄ are 0.1 mg/kg) after a proper period of aeration. The continuous use of the two compounds as fumigants would not cause residue problem.

The temperature of all fumigated grain was reduced to the level of air temperature at the end of treatment including the heated pile by *R. dominica*.

The cost of using the mixture was much lower in comparison with that of using chloropicrin in China.

In summarizing the series of trials, the authors hold that the use of CS₂ and CCl₄ mixture as an alternative to phosphine or as a transitional measure for control of multiplicate and rampant *R. dominica* and other species of stored grain insects under given conditions is feasible.

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