# DEMONSTRATION OF METHYL BROMIDE ALTERNATIVES FOR BAGGED WHEAT IN SYRIA

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## Introduction

Methyl bromide (MB) is routinely used in Syria to control insects in stacks of bagged wheat. A UNIDO funded project was undertaken to demonstrate that carbon dioxide ($CO_2$) or phosphine, supplied from a conventional solid formulation or from a cylinder-based source of 2% phosphine, offered viable alternatives to the use of MB in terms of efficacy, safety and cost. Phosphine has already been used in Syria but there was particular concern about the risk of fire when treating stacks built in the open. $CO_2$ is not currently used in Syria for the disinfestation of wheat.

## Materials and Methods

Phosphine releasing sachets, trade name Gastoxin, (Caso Barnardo, Brazil), $CO_2$ and MB supplies were available in Syria. ECO2FUME cylinders were imported via Cyprus to provide the cylinder-based supply of phosphine.

### *Experimental Stack Design and Construction*

Twelve 25 tonne stacks of bagged wheat, were constructed, six in a large concrete store and six outside on a concrete surface. Each stack was built on a PVC 6 m x 6 m base sheet placed on a 125 μm polythene sheet for protection. Each stack contained 224 bags in 7 layers of 32. Pallets were inserted in some stacks between the bottom layers of bags to provide a gap for insertion of phosphine sachets to avoid contact with the sheets and exposure to condensation. Gas sampling lines, thermocouples and cages containing older immature stages of the rice weevil *Sitophilus oryzae* (L.) were placed along a transept of each stack in three positions at a bottom corner, centre and top corner before sealing the stacks.

### *Stack Sealing and Dosing*

The stacks were sheeted using 9 m x 9 m fumigation sheets fitted with two 1.5 inch ports sealed with caps. The ports were positioned so that one was near ground level on one side of the stack and the other was on the top of the stack. The canopy sheet was glued to the fumigation base sheet with PVC glue, the two were rolled together at the joins and the seal was reinforced with sand bags. Three stacks inside the store and three stacks outside were allocated for each fumigant. Stacks were dosed with MB at the summer rate used in Syria, 25 g $m^{-3}$. The concentration of MB was monitored using a thermal conductivity meter and the stacks were aired after 24 hours. For $CO_2$ treatments a half-life pressure test was performed on each stack. Each stack was dosed using a vaporiser via a valve fitted at the port near ground level and with the port at the top open. The concentration of $CO_2$ at the top port was monitored using an Anagas CD95 infra-red $CO_2$ analyser until the

concentration was greater than 70 % when dosing was stopped. Each stack for treatment with the aluminium phosphide formulation was dosed at a rate of about 5 g/tonne using 11 sachets. The ECO2FUME was dosed via a regulator through a valve fitted at the ground level port to just over 3 g phosphine per tonne. Concentrations of phosphine were analysed using an Agridox phosphine monitor.

**Results and discussion**

*Methyl bromide control standard*

The concentration time products (CTP's) of MB achieved all exceeded 150 g h $m^{-3}$, more than sufficient to achieve complete control of all bioassay insects at the high temperatures prevailing throughout the treatments (Tables 1 and 2).

*Carbon dioxide*

The level of seal obtained on the stacks under local conditions, even with rigorous attention to sealing, varied from 14 to 25 seconds (Table 3), well below the level required for a one-shot $CO_2$ treatment. It proved impractical to dose the outdoor stacks with $CO_2$ because of wind but good results were obtained indoors. The $CO_2$ stack nearest the front entrance caught the sun during the day and perhaps some wind, and required the addition of $CO_2$ every second day to keep levels above 40%. As a result this stack required the addition of over twice as much $CO_2$ during the treatment as the others. Temperatures remained high throughout the exposures, averaging over 30$^{o}$C inside the stacks with day time maxima in the shed of 32 $^{o}$C (Table 1). All test insects inserted in the stacks, whether removed after 10 or 15 days, were killed.

*Phosphine*

Dosing of stacks inside the store with both formulations gave consistently good results with at least 0.6 g $m^{-3}$ phosphine remaining at the end of 7 days. There was no need to top up the dose of phosphine. There was more variation in concentration with the sachets than with ECO2FUME and temperatures were slightly higher than in other trials, reaching a maximum of 34$^{o}$C indoors (Table 1). Outdoors the daily strong winds (Table 1) adversely affected gas retention in all stacks. With both formulations the sealing of the stack in the direct path of the wind was damaged and had to be re-sealed and re-dosed, in each case resulting in each case in a combined dose of about 10 g of phosphine per tonne of wheat (Tables 4 and 5). The other two replicates were sheltered from the wind by the first stack and did not require topping up. All CTP's obtained exceeded 160 g h $m^{-3}$ and all test insects were killed. Mean CTP's for indoor treatments for the two formulations revealed that in spite of a 30% lower dose applied for the stacks treated with ECO2FUME, the mean CTP achieved was only 20% lower (Table 6).

The trials successfully demonstrated that phosphine in particular could be used as a safe alternative to MB within stores, or outdoors if sheltered from the wind, for treatment of bagged wheat. As leakage is related to surface area rather than volume, even better results may be expected from the larger stacks of 100 to 300 tonnes that are normally treated.

**Table 1. Wind and Temperature Data For The Fumigation Treatments**

| Location | Treatment | Day time Temperature range in the stacks (°C) | Wind Speed (m/s) | | Maximum - Minimum ambient Temperature indoors (°C) |
|---|---|---|---|---|---|
| | | | Average | Maximum Gust | |
| Inside | MB | 29-35 | - | - | 31-24 |
| | Carbon dioxide | 30-33 | - | - | 32-22 |
| | ECO2FUME | 28-30 | - | - | 32-22 |
| | Aluminium phosphide | 28-33 | - | - | 34-23 |
| Outside | MB | 30-38 | 4.5 | 9.6 | - |
| | ECO2FUME | 29-37 | 4.0 | 9.3 | - |
| | Aluminium phosphide | 32-37 | 2.5 | 8 | - |

**Table 2. Dosage Rates and Concentration-Time Products For The Methyl Bromide Treatments**

| Location | Dose (Kg) | Dosage Rate (g/tonne) | CTP (g h $m^{-3}$) | | | |
|---|---|---|---|---|---|---|
| | | | Position 1 | Position 2 | Position 3 | Average |
| Inside | 0.90 | 35 | 366.3 | 472.8 | 346.0 | 335.1 |
| | 0.70 | 27 | 234.4 | 192.7 | 336.3 | |
| | 0.78 | 30 | 286.9 | 358.1 | 422.3 | |
| Outside | 0.76 | 30 | 359.5 | 237.5 | 276.8 | 304.7 |
| | 0.80 | 31 | 374.4 | 338.5 | 370.4 | |
| | 0.76 | 30 | 305.0 | 172.1 | 308.2 | |

**Table 3. Dosage Rates and Concentration Data For Trials Using Carbon Dioxide**

| Pressure Decay Tests | | Initial Dose(Kg) | No. of Times Redosed | Total Dose (Kg) | Mean Concentration (%) | | |
|---|---|---|---|---|---|---|---|
| 1000 to 500 Pascals (seconds) | 500 to 250 Pascals (seconds) | | | | Position 1 | Position 2 | Position 3 |
| 22.7 | 24.7 | 46.32 | 4 | 61.68 | 50.5 | 50.9 | 52.1 |
| 14.9 | 16.8 | 42.70 | 1 | 46.70 | 54.8 | 55.4 | 57.3 |
| 18.9 | 21.4 | 61.94 | 7 | 123.10 | 51.9 | 52.3 | 55.8 |

**Table 4. Dosage Rates and Concentration-Time Products For Trials Using 2% Phosphine in Carbon Dioxide**

| Location | Initial Dose (Kg of mixture) | No. of Times Dosed | Total Dose (Kg of mixture) | Dosage Rate (g/tonne of phosphine) | CTP (g h $m^{-3}$) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Position 1 | Position 2 | Position 3 |
| Inside | 4.18 | 1 | 4.18 | 3.25 | 291.0 | 285.2 | 327.3 |
| | 4.02 | 1 | 4.02 | 3.12 | 261.8 | 263.0 | 301.9 |
| | 4.14 | 1 | 4.14 | 3.22 | 215.7 | 214.2 | 261.3 |
| Outside | 4.46 | 3 | 13.22 | 10.29 | 190.5 | 187.0 | 189.2 |
| | 4.66 | 1 | 4.66 | 3.63 | 206.8 | 200.5 | 206.4 |
| | 4.05 | 1 | 4.05 | 3.15 | 237.8 | 233.2 | 236.9 |

**Table 5. Dosage Rates and Concentration-Time Products For Phosphine Trials Using Solid Formulation**

| Location | Initial dosage rate (g/tonne of phosphine) | Top-up dosage rate (g/tonne of phosphine) | Total dosage rate (g/tonne of phosphine) | CTP (ghm$^{-3}$) | | |
|---|---|---|---|---|---|---|
| | | | | Position 1 | Position 2 | Position 3 |
| Inside | 4.7 | 0 | 4.7 | 267.8 | 249.6 | 320.2 |
| | 4.7 | 0 | 4.7 | 351.3 | 329.2 | 405.2 |
| | 4.7 | 0 | 4.7 | 375.5 | 329.9 | 397.0 |
| Outside | 5.1 | 4.3 | 9.4 | 171.6 | 166.7 | 174.5 |
| | 5.1 | 0 | 5.1 | 306.3 | 314.8 | 308.6 |
| | 5.1 | 0 | 5.1 | 450.2 | 441.4 | 461.7 |

**Table 6. Average Concentration-Time Products For The Phosphine Treatments**

| Location | Formulation | Mean Dosage Rates (g/tonne) | Mean CTP (g h $m^{-3}$) |
|---|---|---|---|
| Inside | Aluminium phosphide | 4.7 | 336.2 |
| Inside | ECO2FUME | 3.21 | 269.0 |
| Outside | Aluminium phosphide | 6.5 | 310.6 |
| Outside | ECO2FUME | 5.69 | 209.8 |