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Agricultural Research Center
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Report on Methyl Bromide Phase-out in Horticulture and Commodity Fumigation Sectors In Egypt

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Final Report

Contractor's Personnel

Names and Project Function of the Contractor's Key Personnel

Name	Project Function
Dr. Ayman F. Abou-Hadid	Subcontract Coordinator and Team Leader
Dr. Nagi Abou-Zeid	Small-Scale Farmers Program and Expert Pathologist
Dr. Usama Ahmed El-Behairy	Strawberry Expert
Dr. Samy Abdel Gawad	Horticulture Expert
Dr. Magdy El Hariri	Grain and Structure Fumigation Specialist

Background

Three previous reports had been submitted to present and indicate what had been done in certain times of this, second, phase of the project. Those previous reports focused on establishing the experiments, training the small farmers and evaluating the efficacy of the used alternatives in controlling, soil-borne fungal and nematode plant pathogens. Similar procedures were carried out on the stored cereals and cereal storage specialists.

Results from the three previous reports were positive and encouraging to go on and continue the experiments as most of the used alternatives were efficient in controlling the soil-borne disease in different vegetable and ornamental crops and the insects of the stored cereals. Some of the used alternatives were as efficient as the out-phasing methyl bromide.

This report is the final report with a comprehensive conclusion of the obtained results through out the season. The report will focus on the yield and the cost of using the MBr-alternatives compared to using methyl bromide.

- Following up the results of the previous workshops and field days:

  Wrapping up the results of workshops and field days and concluding recommendations that will help the growers, farmers and cereal storage specialists in the future, especially with the gradual reduction of methyl bromide. any evolved problems.

- **Yield of the cultivated crops and the cost were calculated and reported then analyzed to be compared with those results from the methyl bromide.**
- **The incremental cost was calculated for each treatment to determine the feasibility of using it as an alternative to methyl bromide.**

- **Final results were discussed with farmers, growers, work team and the different participants and different views were considered to excel the process of alternating the phasing-out methyl bromide.**

List of participant growers (as leaders farmers)

Participant	Location	Crop(s)
Ahmed Yakot	**El-Khatatba**	**Tomato- Pepper**
Eid Soliman	**Shben-Elkanater**	**Strawberry**
Nabhan Salem	**Shben-Elkanater**	**Strawberry**
Saad Ali Ahmed	**Shben-Elkanater**	**Strawberry**
Mostafa Monshar	**Shben-Elkanater**	**Strawberry**
Floramix Company.	**El-Mansouria**	**Chrysanthemum-Moresella**

The above mentioned participants (growers) were selected based on:

- Their previous history of using MBr as all of them have used MBr in their farms and started to suffer from the non-availability of the MBr quantity that they used to use in the previous years.

- Their leadership in their areas as most of them are leaders farmers as they will be models for other farmers.

- The diversity of the crops they are growing and were a subject to MBr usage was also considered.

Results

Data in Table 1 show the yield of Chrysanthemum treated with the used MBr- alternatives from greenhouse experiment. No difference was observed among the used alternatives regarding to the yield, however all the used alternatives were less costly than MBr. This is a very good and positive result as the used alternatives were as good as the use of MBr in addition to that they are safer than MBr, especially that Chrysanthemum is an exportable ornamental plant.

Table 1: The yield and incremental costs of MBr-alternatives compared to the costs of MBr at the rate of 50g/m^2 + plastic malsh in Chrysanthemum grown in greenhouse at Floramix Company (2009/2010).

Treatment	Yield (Kg/m^2)	Costs (LE/Kg)	Incremental Costs (LE/Kg)
Basamid (50 g/m^2) + Soil Solarization	72	0.045	**-0.001**
Metam Sodium (100 ml/m^2) + Soil Solarization	72	0.028	-0.018
Soil Solarization + (Bioarc+Biozeid, 216 kg/ha each).	72	0.032	**-0.014**
Methyl Bromide	72	0.046	

In Table 2, The use of methyl bromide gave a little higher yield of moresella compared to the yield from the other used alternatives. Regarding to the cost, the use of basamide

Table 2: The yield and incremental costs of MBr-alternatives compared to the costs of MBr at the rate of 50g/m^2 + plastic malsh in Moresella grown in greenhouse at Floramix Company **(2009/2010).**

Treatment	Yield (Kg/m^2)	Costs (LE/Kg)	Incremental Costs (LE/Kg)
Basamid (50 g/m^2) + Soil Solarization	97	0.033	**0.000**
Metam Sodium (100 ml/m^2) + Soil Solarization	98	0.021	-0.012
Soil Solarization + (Bioarc+Biozeid, 216 kg/ha each).	97	0.024	**-0.009**
Methyl Bromide	100	0.033	

(50 gm/m^2) was the same of using MBr at 50 gm/m^2 , while the use of the other alternative showed very little higher cost which may consider negligible. This also another positive result with another exportable ornamental plant.

Table 3: The yield and incremental costs of MBr-alternatives compared to the costs of MBr at the rate of 50g/m^2 + plastic malsh in Tomato grown in greenhouse at Ahmed Yakot (2009/2010).

Treatment	Yield (Kg/m^2)	Costs (LE/Kg)	Incremental Costs (LE/Kg)
Basamid (50 g/m^2) + Soil Solarization	6	0.54	**+0.17**
Metam Sodium (100 ml/m^2) + Soil Solarization	6.5	0.31	-0.06
Soil Solarization + (Bioarc+Biozeid, 216 kg/ha each).	6	0.39	**+0.02**
Methyl Bromide	9	0.37	

The yield of tomato was higher in the methyl bromide treatment compared to those of other MBr-alternatives in a greenhouse experiment at Elkhatatba. The increase in yield due to the use of methyl bromide was about 50% compared to the used alternatives.

Regarding the cost, the use of basamid or the biofungicides showed a higher cost by 17 and 0.02%, respectively. On the other hand, using metam sodium gave a 0.06% less cost than that of using the methyl bromide (Table 3).

Table 4: The yield and incremental costs of MBr-alternatives compared to the costs of MBr at the rate of 50g/m^2 + plastic malsh in Pepper grown in greenhouse at Ahmed Yakot (2009/2010).

Treatment	Yield (Kg/m^2)	Costs (LE/Kg)	Incremental Costs (LE/Kg)
Basamid (50 g/m^2) + Soil Solarization	3.5	0.93	**+0.37**
Metam Sodium (100 ml/m^2) + Soil Solarization	4	0.15	-0.05
Soil Solarization + (Bioarc+Biozeid, 216 kg/ha each).	3.5	0.66	**+0.1**
Methyl Bromide	6	0.56	

In Table 4 and under the same conditions, the yield of pepper was higher in the methyl bromide treatment compared to the yield from any of the used alternatives. The yield increase due to the use of methyl bromide was more than 50% higher that

yield from any other alternative. Among the used alternatives, the yield for metam sodium was slightly higher than that from basamide or the biofungicides.
The cost of yield was higher when using basamide or the biofungicides by 37 and 1%, respectively, compared to the cost of using methyl bromide at 50 gm/m^2. On the other hand the use of metam sodium showed 5% yield cost when compared to that of using methyl bromide.

Table 5 : The yield and incremental costs of MBr-alternatives compared to the costs of MBr at the rate of 50g/m^2 + plastic malsh in Strawberry grown in field at Eid Soliman (2009/2010).

Treatment	Yield (Kg/m^2)	Costs (LE/Kg)	Incremental Costs (LE/Kg)
Basamid (50 g/m^2) + Soil Solarization	6.6	0.49	**-0.025**
Metam Sodium (100 ml/m^2) + Soil Solarization	6.2	0.327	-0.188
Soil Solarization + (Bioarc+Biozeid, 216 kg/ha each).	7.2	0.321	**-0.194**
Methyl Bromide	6.5	0.515	

Table 5 shows that yield of strawberry from the biofungicides (7.2 kg/ m^2) or basamid (6.6 kg/ m^2) was higher than that from methyl bromide (6.5 kg/ m^2) and metam sodium (6.2 m^2). Regarding to yield cost, all the used alternatives were less costly than that of methyl bromide. The reduction in cost ranged from 2.5 to 19.4% compared to the cost of using methyl bromide in Shben-Elkanater area.

Table 6: The yield and incremental costs of MBr-alternatives compared to the costs of MBr at the rate of 50g/m^2 + plastic malsh in Strawberry grown in field at Nabhan Salem (2009/2010).

Treatment	Yield (Kg/m^2)	Costs (LE/Kg)	Incremental Costs (LE/Kg)
Basamid (50 g/m^2) + Soil Solarization	6.0	0.541	**-0.008**
Metam Sodium (100 ml/m^2) + Soil Solarization	6.3	0.322	-0.227
Soil Solarization + (Bioarc+Biozeid, 216 kg/ha each).	6.5	0.356	**-0.193**
Methyl Bromide	6.1	0.549	

Results from Tables 6, 7 and 8 show the strawberry yield from three different locations in Shben-Elkanater. The strawberry yield from the methyl bromide

treatment was similar, slightly higher or slightly lower than the yield of other treatments.

Table 7: The yield and incremental costs of MBr-alternatives compared to the costs of MBr at the rate of 50g/m^2 + plastic malsh in Strawberry grown in field at Saad Ali Ahmed (2009/2010).

Treatment	Yield (Kg/m^2)	Costs (LE/Kg)	Incremental Costs (LE/Kg)
Basamid (50 g/m^2) + Soil Solarization	5.8	0.560	**+ 0.002**
Metam Sodium (100 ml/m^2) + Soil Solarization	5.9	0.344	-0.224
Soil Solarization + (Bioarc+Biozeid, 216 kg/ha each).	6.0	0.386	**-0.172**
Methyl Bromide	6.0	0.558	

The metam sodium and biofungicide treatments were superior, in most cases, regarding to the yield of strawberry in most locations of Shben-Elkanater area.

Table 8: The yield and incremental costs of MBr-alternatives compared to the costs of MBr at the rate of 50g/m^2 + plastic malsh in Strawberry grown in field at Mostafa Monshar (2009/2010).

Treatment	Yield (Kg/m^2)	Costs (LE/Kg)	Incremental Costs (LE/Kg)
Basamid (50 g/m^2) + Soil Solarization	2.69	1.21	**+0.13**
Metam Sodium (100 ml/m^2) + Soil Solarization	3.12	0.650	-0.48
Soil Solarization + (Bioarc+Biozeid, 216 kg/ha each).	3.94	0.587	**-0.49**
Methyl Bromide	3.1	1.08	

Regarding the yield cost, almost all the used alternatives were less costly compared to the use of methyl bromide. This is a good indication of the success of using those alternatives in the process of producing strawberry.

Conclusion

Regarding to yield and incremental cost:

- **All the used alternatives gave acceptable yield of the under-experimentation vegetables and ornamental plants showing their feasibility as successful alternatives for the out-phasing methyl bromide.**
- **The used alternatives were successful in giving good yield of tomato, pepper, strawberry, Chrysanthemum and Moresella indicating the efficacy of these alternatives on different crops. This an encouraging advantage to use those alternative on a wider variety of other different crops.**
- **Using these alternatives at different geographical locations with a varied weather conditions indicated the stability of those alternatives under different conditions giving the ability to use them in different areas and different circumstances.**

Regarding reduction of fungal and nematode diseases:

(data was presented in the previous report)

- **All the used alternatives gave reasonable reduction of the occurrence of the pathogenic fungi which are mainly the causal agents of root rots and wilt diseases for several host plants.**

- **Methyl Bromide still to be the superior treatment as in most cases it showed significant increase in reducing the occurrence of the pathogenic fungi compared with the used alternatives. However, the efficacy of some alternatives, in some cases, was close to that of Methyl Bromide.**

- **Among the used alternatives, Soil Solarization +Basamid (50g/m^2) was the most effective one after the Methyl Bromide.**

- **The efficacy of both Soil Solarization + Metam sodium (100 ml/m^2) and Soil Solarization + (Bioarc+Biozeid, 216 kg/ha each) in reducing the occurrence of the pathogenic fungi came after that of the Soil Solarization + Basamid (50 g/m^2).**

- **The efficacy of the used MBr-alternatives in reducing the occurrence of the pathogenic fungi ranged from 56 to 87.6 % while that of Methyl Bromide ranged from 60-94.3%.**

Summary for result of nematode reproduction indicated that the used treatments had a same trend to that on the occurrence of the pathogenic fungi as:

- **All the used alternatives gave reasonable reduction of the root-knot nematodes.**
- **The super efficacy on reducing nematode reproduction was to the Methyl Bromide treatment**

- **The used alternatives shared the superiority in reducing the nematode reproduction.**
- **It is noteworthy that the used biological compounds (Bioarc&BioZeid) were more effective on nematode reproduction than it was on the occurrence of the pathogenic fungi.**

Recommendation

- **Science the used MBr-alternatives showed a good effect on reducing the soil disease problems with giving an acceptable yield compared to methyl bromide, they are recommended to replace the out-phasing methyl bromide.**
- **The successful use of these alternatives encourage people to use them on a large scale with more and more crops and in various geographical locations.**
- **As the used alternatives cost similar, slightly higher or lower than the cost of using methyl bromide, they are recommended to be used and give the growers the desired profit.**
- **As the used alternative either the chemical or the biological ones are register for use in Egypt they are recommended to used safely and easily.**
- **More awareness and experimentation are needed with some other small growers in different locations with more participation of the governmental agricultural extension.**

Storage cereals

Methyl bromide alternatives in storage project

Introduction:

1- Egypt with a population of about 80 millions has a total annual consumption of wheat grain in the vicinity of 14 million tons.
About 50% of this amount derives from local production while the remaining 50% has to be imported.
Most of the local production is stored in shounas, which are open storage areas. Stored bagged cereals in shounas required treatment in the farm of fumigation at least once depending on the duration of storage.
Moreover, imported wheat is usually stored in soils located at different sites in the country until milled.
The duration of storage varies depending on the milling needs and can last up to 6 months in such cases fumigation is needed.
Pest control in stored grains and their products are achieved generally by Methyl Bromide (MB).Due to the fact that MB causes about 5-10 % of total Ozone depletion in the earth's stratosphere, increase the level of U.V. radiation, which has been linked to skin cancer, eye cataracts and degradation of immune system, the Montréal Protocol (1997) declared the phase – out of MB in industrialized countries by the year 2005.
Phosphine is extensively used to fumigate durable commodities and has considerable potential for replacing Methyl Bromide. It is generated in practice by the action of moisture in ambient air on metal Phosphide (Aluminum or Magnesium).
Phosphine fumigation doesn't produce toxic residues and has no adverse effect on the viability of seeds (El-Lakwah and Khattab, 1989)

Studies on the effect of PH3 gas tablets (3g.) Gastoxin aluminum phosphide at Exposure period of five days at the rate of 1.5,2 and 3 tablets /m^3 on the all stages of the most common stored product insect pests in Egypt under plastic sheet in shounas at five governorates Sharkia (Mashtool),Gharbia (Santa),Beheira (Rahmania),Fayoum (Tamia) and Bani suef (Ahnasia) and 3days exposure period at the rate

of 2 and 3 tablets /m^3 on the same stages of the most stored products insects in 2 governorate Dakahlia (El mansura shouna) and Fayoum (Taton shouna) and training and field day on the technique of fumigation under sheet and apparatus of monitoring PH3 gas and grain temperature and moisture content of grain in shounas.

Here in a description of the work that was done:

Application of Methyl Bromide alternatives in grain storage project

1. Contact with the principal bank for development and agricultural credit (PBDAC) is presented which shows a total storage capacity of approximately 3.2 million m^2 of the shounas.
2. Prepare the ideal lot in shounas.
3. Prepare the sheet treated against the sun rays.
4. Prepare the apparatuses of monitoring the moisture content of grain and temperature and the concentration of (ptt3) gas and tablets (Gastoxin).
5. Experiments in seven governorates were Sharkia, Gharbia, Behira and Dakahlia in north Egypt, Fayoum and Beni suef in south Egypt by using phosphine gas tablets under sheet at rates of 1.5,2 and 3 tablets per cubic meter in winter and summer, one shounas in these governorates for exposure time five days in five governorates and three days in two governorates.
6. Training activities will led to the needed technology transfer aiming to facilitate the introduction of high quality fumigation procedures, to assure the application of good storage practices and hygiene standards, to follow high safety conditions for pest control personal and environmental as well as to prepare the future introduction of other Methyl Bromide alternatives.

Results obtained from using PH3 tablets at the rate of 1.5, 2 and 3 tablets/m^3 (PBDAC) shounas

Mashtool shouna:

Percent mortality of adults of *S. oryzae* ,*R. dominica* and *T. castaneum* and active and diapause larvae of *T. granarium* in response to Phosphine gas under sheet on Concrete floor at 5 days exposure.

Adult of *S. oryzae* , *R. dominica* and *T. castaneum* showed 100% mortality as a result of applying (2 and 3 tablets/m^3) for either 5 days .The same result was found for the active and diapause larvae of *T. granarium* the mean of moisture content of wheat grain and temperature were 11.3% and 32.3C°

- Effect of Phosphine gas on the mortalities of the developmental stages of test insects exposed to 5 days under cover and incubated for 45 days after treatment, relative the control on **concrete floor**.

As to the effect of such treatment on the developmental stages of tested insect pests, it was found that 5 days exposure led to 100% mortality of all stages at the 2 and 3 tablets per cubic meter dose except egg and pupae of S. *oryzae* at L_3 and L_1 gave 98 and 96% mortality respectively and also of *R. dominica* larvae at the high and middle level showing 99 and 99.3% mortality, respectively.

- Average concentration of Ph_3 (ppm) under tarpaulin (1.5, 2 and 3 tablets/m^3) on concrete floor.

- Monitoring gas concentration under sheet it was found to be 814,1050 and 1303 ppm in the first day increasing to 937,1370 and 1545 ppm in the second day within the three doses 1.5 , 2 and 3 tablets / m^3,then started to decline over time. However, Its average were 790,6,1118 and 1086.6 ppm, respectively.

- **Santa Shouna:**
- Percent mortality of adults of tested insects in response to Phosphine under cover on clay soil at 5 days exposure.

The effect of the same treatments revealed that complete mortality was found with all adults and larvae, at 2 and 3 tablets /m^3 except diapause larvae gave 90,93 and 96% mortality at L_1,L_2 and L_3 for 2 tablets/m^3 for *T. granarium* , respectively.

- Effect of Phosphine on the viability of the developmental stages of test insects after being incubated for 45 days following fumigation for 5 days exposure under cover relative the control on clay soil.

- With respect to the developmental stages of different insects, complete mortality was experienced in 2 and 3 tablets/m^3 except for egg and pupae for *S. oryzae* at L_3 and L_1 was found 99.3 and 98% mortality and pupae of *R. dominica* at L_1 and L_3 was found 98 and 96% mortality at 2 tablets/m^3 .

The average concentration of PH3 after 5 days exposure were 902,861 and 1664 ppm for 1.5, 2 and 3 tablets/m^3 under sheet.

Rahmania Shouna:

- Percent mortality of adults of *S. oryzae* ,*R. dominica* and *T. castaneum* and active and diapause larvae of *T. granarium* in response to Phosphine gas under cover on clay soil at 5 days exposure.

Aluminum Phosphide at the rate of 1.5,2 and 3 tablets (3g each)/m^3 resulted in 100% mortality of adults and active larvae of *T. granarium* except diapause larvae was found 88,97,80,98,99 and 99.3% mortality at rate of 1.5 and 2 tablets/m^3 at L_1,L_2 and L_3 respectively.

- Effect of Phosphine gas on the mortality of the developmental stages of test insects exposed after being incubated for 45 days following fumigation for 5 days under cover, relative the control on **clay soil**.

Complete mortality was experienced for all stages of tested insects (eggs, larvae and pupae) were found at the rate of 2 and 3 tablets/m^3 except pupae of *S. oryzae* at level one gave 98% mortality at the rate of 2 tablets/m^3

- Concentration of PH_3 (ppm) under sheet at El Rahmania Shouna (1.5, 2 and 3 tablets/m^3) on clay soil. The average concentration of PH3 under sheet were 726.8, 139.8 and 1815 ppm at rate of 1.5 ,2 and 3 tablets /m^3 respectively.
- **(Tamia Shouna)**
- Percent mortality of adults of *S. oryzae* ,*R. dominica* and *T. castaneum* and active and diapause larvae of *T. granarium* in response to Phosphine gas under sheet on sand soil at 5 days exposure.

- Mortalities were calculated after 5 days exposure. Adults of tested insects showed 100% mortality as a result of applying 2 and 3 tablets/m^3.

The same result was found for the active and diapause larvae of *T. granarium* in the mean of moisture content of grain and grain temperature are 10.6% and 26.3 C°.

- Effect of Phosphine gas on the mortality of the developmental stages of test insects after being incubated for 45 days following fumigation for 5 days under cover, relative the control on **sand soil**.

As to the effect of such treatment on the developmental stages of tested insect, it was found that 5 days exposure led to 100% mortality at the rate of 3 tablets/m^3.

Egg, larvae and pupae of *S. oryzae*, *R. dominica* and *T. castaneum* mortality % at the rate of 2 tablets/m^3 ranged between were (90 – 100%),(90 – 100%) and (93 – 100%) respectively.

- Concentration of Phosphine gas PH_3 (ppm) under plastic sheet at Tamia Shouna following the use of Aluminum Phosphide tablets (1.5, 2 and 3 tablets/m^3) on sand soil.

- The concentration of PH_3 gas under sheet, it was found to be 588,892 and 962 ppm in the first day at the rate of 1.5,2 and 3 tablets/m^3 respectively, increasing to 909,1575 and 1682 ppm in the third day then started to decline over time. However it averaged 745.4, 1054.4 and 1173.4 ppm respectively.

The tested phosphine fumigation proved to be effective against the different stored grain insect in the shounas. Use of 3 tablets (3g) from aluminum phosphide /m^3 at 5 days exposure in grain temperature from 25^0c to 32^0c.

The adult and immature stages gave 100% mortality.
Grain fumigation on concrete floor,clay and sand soil in shounas the same effect meanwhile the type of ground soil not effect on the fumigation by using phosphine tablets.
The concentration of phosphine tablets under sheet depend on the moisture content of grain (m.c) and relative humidity **(RH)** the high concentration of **PH3** gas found 1815 ppm in Rahmania shouna because the (m.c) of grain is 13.2% this Beheira governorate in the nourth of Egypt.

Recommendation :
The use of phosphine tablets at the rate of 3 tablets (3g.)/m3 at the shounas on the different ground soil under new plastic sheet at grain temperature from (25-32^{0}c) and (m.c) of grain from 10.6 to 13.2% gave 100% mortality of tested insects.

Ahnasia Shouna :
Percent mortality of adults of *S. oryzae* ,*R. dominica* and *T. castaneum* and active and diapause larvae of *T. granarium* in response to Phosphine gas under cover on ground sheet at at 5 days exposure.
Assessment of the effect of Phosphine gas at rate of 2 and 3 tablets / m^3 revealed that complete mortality was found with all adults and the *T. granarium* larvae of the tested insects after 5 days exposure except level one and two the diapause larvae gave 95 and 96% mortality at the rate of 2 tablets / m^3.

- Effect of PH_3 gas on the mortalities of the developmental stages of test insects exposed to 5 days under cover and incubated for 45 days after treatment on **ground sheet**, relative the control .
- With respect to the developmental stages of different insects, complete mortality was clear in case of *T. castaneum,* eggs and larvae of *R. dominica* and eggs of *S. oryzae* at the rate of 3 tablets/m^3.

But the pupae of *S. oryzae* and *R. dominica* at the rate of 2 and 3 tablets/m^3 at the levels one, two and three were 92,95,93,96,95,100,83,85,86,97,98 and 96% mortality respectively.

Average PH_3 concentrations were 426.4,614.6 and 731ppm at the rate of 1.5, 2 and 3 tablets/m^3 for 5 days exposure.
These results were found because the most of tablets not analysis for the decrease of relative humidity, in the atmosphere and moisture content of grain.

(Taton Shouna)

- Percent mortality of adults of tested insects and active and diapause larvae of *T. granarium* in response to Phosphine gas under sheet on sand soil at 3 days exposure.

The effect of Phosphine tablets at the rate of 2 and 3 tablets/m^3 on the adults and active and diapause larvae of *T. granarium* revealed that complete mortality was found except Diapause larvae were found at three levels at the rate of 2 tablets/m^3 were 97,98and 95% mortality at 3 days exposure .

- Effect of Phosphine gas on the mortalities of the developmental stages of test insects exposed to 3 days under cover and incubated for 45 days after treatment on **sand soil**, relative the control.

No emergence of adults was found in the incubated developmental stages of all tested insects at the rate of 2 and 3 tablets/m^3 for 3 days exposure.

- Concentration of Phosphine gas (ppm) under sheet at Taton Shouna following the use of Aluminum Phosphide tablets (2 and 3 tablets/m^3) on sand soil at 3 days exposure.

The average concentrations of PH_3 gas under sheet in Taton Shouna at the rate of 2 and 3 tablets/m^3 were 991.3 and 1283.3 ppm respectively.

Mansoura shouna

- Percent mortality of adults of tested insects and active and diapause larvae of *T. granarium* in response to Phosphine gas under cover on concrete floor at 3 days exposure.

- The results shown in this table revealed that percentage mortalities of the adults of *S. oryzae*, *R. dominica* and *T. castaneum* and Larvae of *T. granarium* active and diapause larvae raised gradually with the increase of the concentration of PH_3 gas. In case of *S. oryzae* and active larvae of *T. granarium* were complete mortality at the two rates (2 and 3 tablets/m^3) but *R. dominica* ranged between (87 – 100 %) and (92 – 100 % mortality) at the rate of (2 and 3 tablets/m^3), respectively.

The adults of *T. castaneum* mortality percent were found 93,100 and 98% at the rate of 2 tablets/m^3 at the L_1, L_2 and L_3, respectively but at rate of 3 tablets/m^3 ranged between (97- 100% mortality)

Such as Diapause larvae mortality % ranged between (80-87 %) and (83 - 90%) at the rate of 2 and 3 tablets/m^3 respectively.

- The effect of PH_3 tablets at the rate of 2 and 3 tablets/m^3 on immature stages of the tested insects were found all stages of *T. castaneum* and *S. oryzae* complete kill except the egg of *S. oryzae* at level 1 this results obtained at the rate of 3 tablets/m^3.

But *R. dominica* in this concentration mortality % ranged between (92-100% mortality)

Concentration of Phosphine gas PH_3 (ppm) under sheet at Mansoura Shouna following the use of Aluminum Phosphide tablets (2 and 3 tablets/m^3) on concrete floor.

- Average PH_3 concentrations were 670.3 and 938 ppm at the rate of 2 and 3 tablets/m^3 after 3 days exposure with respect to the developmental stages of different insects, complete mortality was experienced in all cases except for *R. dominica* were an extremely low emergence occurred and was attributed mostly to probable natural tolerance in the employed strain.

Generally pupal stages are more tolerant in all tested insects, to PH_3 gas. Adults are more sensitive to the fumigant than other stages *R. dominica* was more tolerant to phosphine than the other tested insects.

Conclusion

The tested phosphine tablets proved to be effective against the different stored grain insects in the shounas.
Phosphine fumigation procedure gave 100% insect mortality after aeration of grain stacks.
Therefore following steps must be undertaken carefully to achieve this result.

- Grain stacks have to be covered well with gas proof sheets.
- Phosphine tablets should be put on plates and distributed between grain stacks.
- The gas tightness of the fumigated stacks under the cover sheet must be checked by using silo check.
- Sealing of the stacks to be fumigated must be don well by using sand snakes or other available materials (sand, earth or soil).
- Use of 3 tablets /m^3 (3g.) at 5 days exposure from $25c^0$ to $32c^0$ gave 100% mortality of the tested insects.
- Use of 3 tablets/m^3 (3 gm) at 3 days exposure in summer gave 100% mortality of all tested insects.
- Generally, pupal stages are more tolerant than eggs in ***Sitophilus orezae*** , ***Rhizopertha dominica*** and ***Tribolium castaneum***.
- Adults are more sensitive to the fumigant than other stages.
- ***Rhizopertha dominica*** was more tolerant to PH3 than other tested insects.
- **Not depend on Phosphine gas alone** (MB) alternative to grain fumigation because some insects build up resestance to phosphine gas but depend on another alternative such as Eco2 Fume gas.

Recommendation

The use of phosphine tablets at the rate of 3 tablets (3g.)/m3 at the shounas on the different soil types under new plastic sheet at grain temperature from (25-32^0c) and (m.c) of grain from 10.6 to 13.2% gave 100% mortality of tested insects (at the winter).But in summer use of PH3 tablets(3g.) at the rate of 3 tablets / m^3 on the different soil under new plastic sheet in shounas at 3 days exposure is good (MB) alternative in storage when methyl bromide phase out.

- Next season we can test another methyl bromide alternatives such as Eco2 Fume gas at other sites.