

Study of the Efficacy of Phosphine on Stored Dates- Insects and its Effects on the Organoleptic Parameters and Residues on Treated Dates

Mohamed Habib DHOUBI*, Asma BEN SALEM, Maria ABDELLEOUI and Wiem HAOUARI

National Institute of Agronomy of Tunisia 43 Avenue Charles Nicolle 1082 Tunis Mahrajene Tunisia.

*Corresponding author email id: dhouibi.med@inat.agrinet.tn

Abstract – A study of the effect of the magnesium phosphide on controlling stored dates-insects was conducted in the laboratory and in a fumigation room of dates in a company. Within modified airtight gas exposure units containing dates at 25°C and 35°C, mixed-age adults of date moth *Ectomyelois ceratoniae*, red flour beetle, *Tribolium castaneum*, and flour moth *Ephestia kuehniella*, were exposed separately during 1, 2, 3, 4 and 5 days to three doses of magnesium phosphide 1, 2 and 3g/m³.

The exposure duration of dates to phosphine gas released from plates depends on fumigation room temperature with an appropriate dose of the fumigant. Within the tested doses mentioned above, the dose 3g/m³ (both from Plate or pellet) was the most convenient one to reach 100% of corrected mortality rate even for the resistant stages (eggs and nymphs). Therefore this dose of 3g/m³ has no side effect on the organoleptic quality (water, total sugar, taste, odor, color and texture....) of the different treated and untreated date's varieties and no residues left in the treated dates.

Keywords – Magnesium Phosphide, Pellets, Plates Stored Dates Insects, Fumigation, Organoleptic Parameters and Phosphine Residue.

I. INTRODUCTION

In Tunisia, date-palm sector occupies a strategic importance in terms of economic, social and environmental development. In fact, an analysis of the competitive advantage of the Tunisian date industry in the Mediterranean area and Iran over the last 20 years shows that Tunisia is still the main supplier of dates to the EU distribution channels [1]. However, one of the major problems facing this sector is pest control on field [2] - [3] - [10], [11]. As well as in packing houses. The most economically important constraints to exported dates is the infestation by the carob moth, *Ectomyelois ceratoniae* and the Mediterranean flour moth *Ephestia kuehniella* [5] These two insect species are reported as the most widespread and abundant moth-pests of stored dates in Tunisia [5] which makes market limitations to dates. In order to tackle market limitations, a rapid disinfestations treatment time is required to fulfill phytosanitary regulations at the time of export. For many years ago, the substance most frequently used for fumigation is methyl bromide (CH₃ Br) [15]. Methyl bromide is a structural fumigant that was used widely in flour mills, cereal processing facilities and warehouses [12]. However, it should be noted that in 1992 methyl bromide was placed under the Montreal Protocol on substances that deplete the ozone layer, [13] and all developed countries are scheduled to eliminate the bulk of

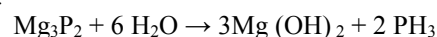
their consumption of methyl bromide by 2005 [14]. During the last years, significant changes have occurred in date packing [8]. Several alternatives to methyl bromide are being considered recently, including carbon dioxide [16], modifying the stored atmosphere by the use of low temperature (Fields, 1992) or high temperature [17], combining a mixture of CO with CO₂ [16].

II. MATERIALS AND METHODS

Chemical Products

The solid fumigant used in our experimental trials is magnesium phosphide. PH₃ gas was generated by decomposition of magnesium phosphide plates or pellets.

The release of magnesium phosphide depends on the moisture of the atmosphere as the following reaction presents.



The magnesium phosphide is available in plates and pellets (Fig.1).

Each plate weighs 117 grams containing 33 grams of phosphine. Plates are wrapped in a waterproof aluminum pack.

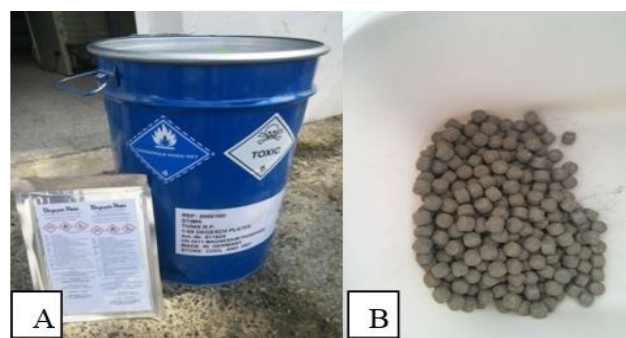


Fig. 1. Magnesium phosphide, A) Plates B) Pellets

2-Insects

In this study we used three main species of insects infesting stored dates such as: date moth *Ectomyelois ceratoniae*, flour moth: *Ephestia kuehniella* and *Tribolium castaneum*.

We took 50 individuals from each stage: eggs, young larvae, old larvae, nymphs and adults of *Ephestia Kuehniella*, 50 adults of *Tribolium castaneum*, these two species are reared in the laboratory under controlled conditions and from 300 to 500 dates severely infested by the date moth *Ectomyelois ceratoniae*. The rearing of *Ectomyelois ceratoniae* in the laboratory is tough so we

used 300 dates fruit heavily infested with date borer for laboratory tests and for plant tests 500 severely infested dates. Laboratory cultures of the test insect *Ephestia kuehniella* were reared under standard conditions of 25±1°C temperature, 60±5% relative humidity and 16/8 photoperiod on an artificial diet. The insects were exposed to fumigant and then removed to Petri dishes each containing a folded paper strips.

Each trial requires two samples of the different species and stages studied, one for control and another to be treated in order to deduce the effect of the treatment to determine corrected mortality.

After each test, all samples were recovered and placed in a programmed incubator under controlled conditions incubated at a temperature 25°C and 75% humidity (fig.2) followed for 25 days to evaluate the insects' situations after treatment, on the other hand, treated or control dates are directly dissected under a binocular microscope to count all the stages either dead or alive.



Fig. 2. The insects closed in boxes and incubated for the following process

A- Study of the Effectiveness of Products

1- At the Laboratory (Pellets)

These tests are carried out by magnesium phosphine pellets at doses of 1g/m³, 2g/m³ and 3g/m³, the fumigation chamber used is 0,067 m³ Volume, for 1, 2, 3, 4, and 5 days fumigation times for each dose, to determine the effective dose and time period that will generate a total corrected mortality of the various stages of the insect species being monitored. This work is carried out at two temperatures of 25°C and 35°C.

For each test; several replicates were made to check the mortality of the stages of insects exposed to phosphine in order to obtain safe and satisfactory results.

Our results were successful when we found 100% of pest mortality. Once we had this rate, we repeated our essays 5 times to confirm the results obtained. (Tables 1 and 2).

Table 1. Number of replicates at 25°C

| | 1 day | 2 days | 3 days | 4 days | 5 days |
|--------------------|--------------|--------------|--------------|--------------|--------------|
| 1 g/m ³ | 2 replicates | 3 replicates | 2 replicates | 2 replicates | 3 replicates |
| 2 g/m ³ | 3 replicates | 5 replicates | 3 replicates | 2 replicates | 2 replicates |
| 3 g/m ³ | 5 replicates | 2 replicates | | | |

Table 2. Number of replicates at 35°C

| | 1 day | 2 days | 3 days |
|--------------------|--------------|--------------|--------------|
| 1 g/m ³ | 5 replicates | 5 replicates | 4 replicates |
| 2 g/m ³ | 5 replicates | 5 replicates | 2 replicates |
| 3 g/m ³ | 5 replicates | 4 replicates | |

2- Tests at the Factory CCPA Boujbal

According to the results of the laboratory tests, at the CCPA plant in Boujbal, which is in the governorate of Nabeul, 65 km from the capital Tunis, we carried out fumigation series with magnesium phosphine plates only at a dose of 3g/m³ and at two temperatures of 25°C and 35°C (Table 3).

Table 3. Number of replicates carried out at the plant at 3g/m³

| Treatment duration | One day | Two days | Three days |
|--------------------|--------------|--------------|--------------|
| Temperature 25°C | 4 replicates | 5 replicates | 2 replicates |
| Temperature 35°C | 5 replicates | 2 replicates | |

The volume of the fumigation chamber at the factory is 104m³, if the chamber is empty, 10 plates must be used, but in order to minimize the number of plates, the fumigation chamber is half filled with infested dates or residues from the harvest. So we will have a half volume and therefore we use only 5 plates (Fig.3).



Fig. 3. Half Fumigation room filled with infested dates in bags

We used laboratory reared insect samples at all stages of *Ephestia Kuehniella* development (eggs, young larvae, old larvae, nymphs and adults), *Tribolium castaneum* (adult stage) and a 3 kg sample of very infested dates by the date moth: *Ectomyelois ceratoniae* (fig. 4).



Fig. 4. Insects and highly infested dates brought from the laboratory placed in the fumigation room

For the tests which gave us a satisfactory result (100% mortality), at 25°C., the duration of the exposure time is two days and for 35°C. the duration is 1 day. We used several date varieties dates such as Deglet nour from Kebili, Deglet nour from Tozeur, Alig from Tozeur; Alig from Kebili and kentichi from Tozeur and placed them in the fumigation room after one day at 35°C and 2 days at 25°C of the treatment we have brought them to the laboratory to make quality analyzes (color, odor, texture and testing) and get an idea about the effect of treatment by the magnesium phosphide plates on the dates (residues).

For each test we recorded the temperature during the fumigation process chamber with a temperature recorder HOBBO (fig5).

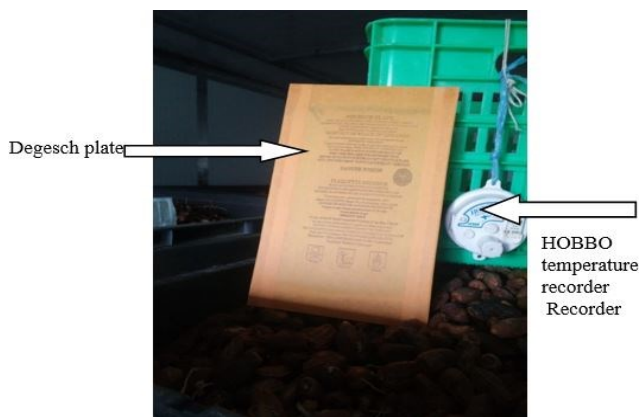


Fig 5: HOBBO temperature recorder and unpackage phosphide plate

At the end of each trial, we measured the rate of PH₃ in the fumigation chamber to know the evolution of PH₃ over time. Because of the lack of measuring equipment at the plant level, we couldn't measure the phosphide rate during our trial. Therefore, the evolution of PH₃ released at both temperatures 25°C and 35°C from the plates was measured in the laboratory chambers similar to those of the plant. The fumigation chamber in the laboratory is of volume 20 m³, the chamber is empty, and we used 2 plates of magnesium phosphide. Measurements were done every hour until the phosphine level reached zero.

3- Evaluation Method for the Efficacy

The efficacy of the treatment is evaluated by the determination of the corrected mortality according to ABBOTT 1925 Formula.

$$= \frac{\text{Corrected mortality}}{\text{mortality in treated insects} - \text{mortality of the control}} \times 100$$

At the end of the control for each trial, the corrected mortality is calculated, which is the difference between the treated mortality and the control mortality.

In all trials, if the corrected mortality rate is 100%, the trial is considered successful.

B. Study of the Effect of Treatment on the Quality of Dates Treated at the CCPA Boujdbel Grombalia

The quality evaluation of the dates was carried out for dates treated with 3g / m³ of magnesium phosphide (dose

giving satisfaction for duration of one day). Ten samples of dates (5 treated and 5 controls) for 25°C and 35°C, from the

Deglet nour variety of Kebili and Deglet Nour of Tozeur, Alig of Tozeur and Alig Kebili and the variety Kentichi of Tozeur, were analyzed in the laboratory accredited for physicochemical analyzes Of the Technical Center for Agri-Food (CTAA). The evaluated parameters are: odor, color; Taste, texture and others) for the mentioned varieties.
C. Study of Phosphine Residues on the Dates Treated by Magnesium Phosphide at the CCPA Grombalia

Dates treated with 3g/m³ (dose satisfying a duration of one day), and ten samples of dates (5 treated and 5 controls) for 25°C and 35°C, from the Deglet nour de Kebili and Deglet Nour de Tozeur, Alig de Tozeur and Alig Kebili and the Kentichi variety of Tozeur, were analyzed in the laboratory of physicochemical analyzes (accredited laboratory) of the National Institute of Research and Physico-chemical under the Ministry of Higher Education and Scientific Research.

III. RESULTS AND DISCUSSIONS

We want to follow the evolution of the gas, we couldn't do it in the factory, there is no enough time, therefore we used an insect rearing room in the laboratory made of sandwich panels as in the factory to follow for 3 days the release of gas, therefore we removed the door handle and we placed a plastic tube to introduce it in the fumigation room in one side and into the detector on the other side.

1- Determination of the Optimum Dose and Pest Exposure Time for Fumigation using Pellets in Laboratory Fumigation Room at 25 and 35°C

*Essays conducted at 25°C

After essaying the following doses: 1g, 2g and 3g/m³, our results showed that the best dose that should be applied on all stages of pests is 3g/m³. This latter dose was the convenient one that achieved 100% of mortality rate (Fig.6) for all the development stages of *Ephestia*. However both of the doses 1g/m³ and 2g/m³ weren't sufficient enough to reach 100% of mortality rate. In fact the most resistant stages was egg instar and nymph instar

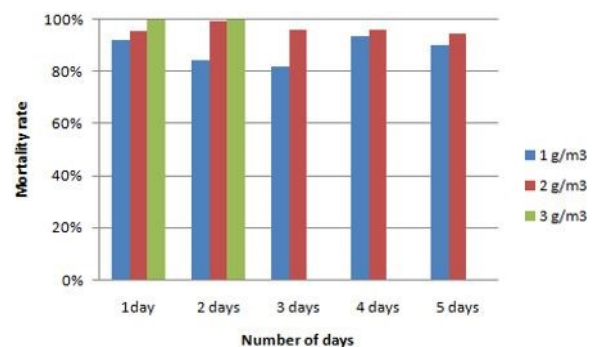


Fig. 6. Corrected mortality rate of Ephestia Kuehniella. At 3 doses of PH₃ for 5 day-treatment time exposure (temperature= 25°C)

The best results of the mortality rate of the Tribolium were reached at a dose of 1g/m³ for 2 days and 3g/m³ for 1 day (Fig. 7).

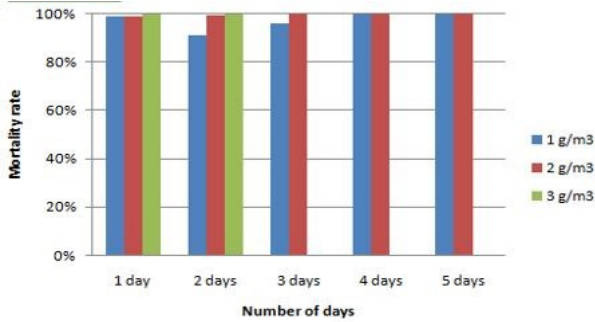


Fig. 7. Corrected mortality rate of *Tribolium castaneum* at 3 doses of PH3 for 5 day-treatment time exposure (temperature = 25°C)

The dose 1g/m³ gave convenient results (100% mortality rate) after 5 day exposure time on *E. ceratoniae*; however the dose 2g/m³ and 3g/m³ gave satisfied results for only one day (Fig 8).

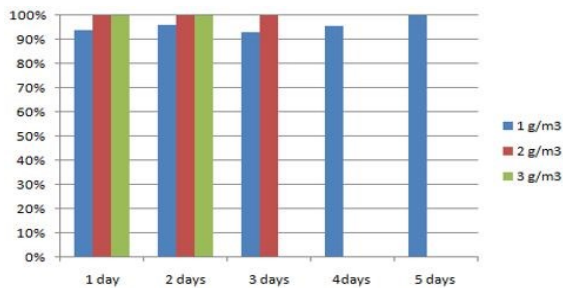


Fig. 8. Corrected mortality rate of *Ectomyelois ceratoniae* exposed to 3 doses of PH3 for 5 day-treatment time (temperature = 25°C)

Due to commercialization factors, the exporters require a short time for treatment. Therefore the dose 3g/m³ seemed to be the most promising for better results.

***Essays conducted at 35°C**

For the doses 1g/m³ and 2g/m³ we obtained successful results (100% of mortality rate) during 2 day exposure time. However the period was reduced to only 1 day with successful results (100% mortality rate) when we applied 3 g/m³ (Fig. 9).

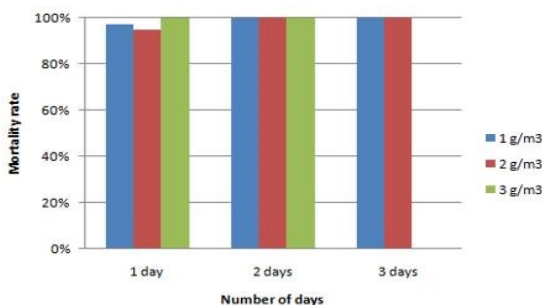


Fig. 9. Corrected mortality rate of *Ephestia kuehniella* exposed to 3 doses of PH3 for 3 day-treatment time (temperature = 35°C)

The dose of 1g/m³ gave successful results after 2 day PH3 exposure time at 35°C. However the same results (100% of mortality rate) was obtained after only 1 day. (Fig. 10).

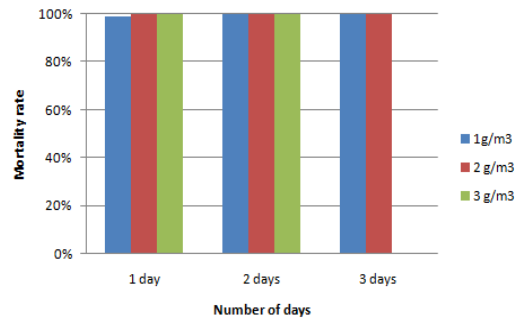


Fig. 10. Corrected Mortality rate of *Tribolium castaneum* at 3 doses of PH3 for 3 day-treatment time exposure (temperature = 35°C)

At 35°C, both of the doses 1g/m³ and 2g/m³, we obtained successful results for *Ectomyelois ceratoniae* after 2 day – treatment exposure. However the period was reduced to only 1 day with successful results (100% mortality rate) when we applied 3g/m³ (Fig. 11)

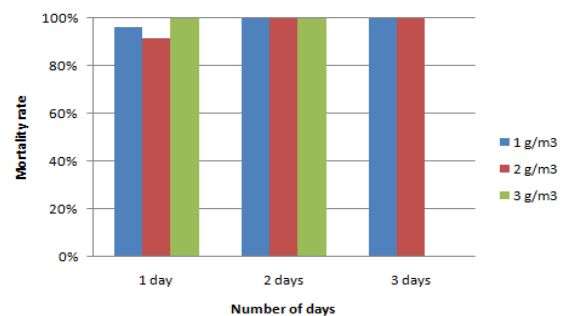


Fig. 11. Corrected mortality rate of *Ectomyelois ceratoniae* exposed to at 3 doses of PH3 for 3 day-treatment time (temperature = 35°C)

2- Determination of the Optimum Dose and Pest Exposure Time for Fumigation using Plates in Plant for the Dose 3g/M3 and for Date Fumigation at 25 and 35°C

*** Essays conducted at 25°C**

For the temperature 25°C, the best pest exposure time to PH3 to the magnesium phosphide plates is two days which allows to totally disinfecting the dates of all types of pests (Fig 12).

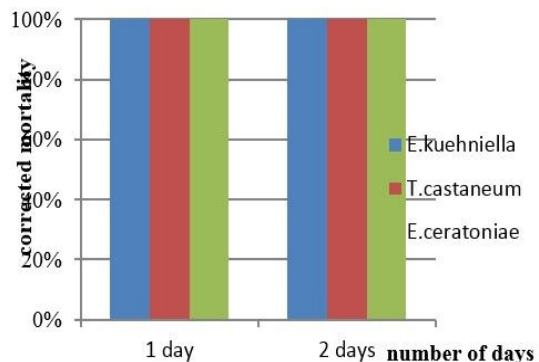


Fig. 12. Corrected mortality of *E. kuehniella*, *E. ceratoniae* and *T. castaneum* at 25°C

We observed that the residual level of the magnesium phosphide plates decreased by increasing the duration time of the fumigation chamber (Tab. 4)

Table 4. Phosphine residues in plates at 25°C

| | 1 day | 2 days | 3 days |
|-----------------------------------|-------|--------|--------|
| Mean of residues in plates in ppm | 12.03 | 0.83 | 0.66 |

***Essays conducted at 35°C**

The best pest exposure time at 35°C was one day (Fig 13)

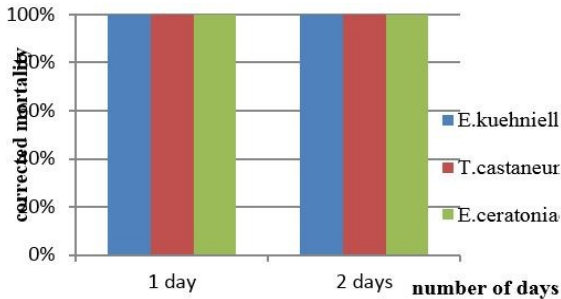


Fig. 13. Corrected mortality of E. kuehniella, E. ceratoniae and T. castaneum at 35°C

At this temperature there is a practically total release of PH3 from plates after two days which was confirmed by measuring the residue at the used plates after one day treatment (Tab 5.)

Tab 5: Phosphine Residues in Plates at 35°C
C-Evaluation of the PH3 Release in the Fumigation Chamber

We want to evaluate the quantity of gas emitted by the plate of magnesium phosphide at the dose of 3g/m³ at 25°C. and at 35°C. during 3 days. It is impossible to do this work at the factory. We conducted this work in the laboratory in an insect rearing room made of sandwich panels just like the factory, by simply removing the door

| | 1 day | 2 days |
|--|-------|--------|
| PH3 mean residue rate in plates in ppm | 14.11 | 0.5 |

handle for introducing a plastic pipe to the middle of the chamber on one side and connecting the other end piece to the gas detector.

At a temperature of 25°C, we noticed that the PH3 level reaches its maximum on the first day. The highest amount of PH3 is recorded after 9 hours after putting the plate inside the fumigation room (fig.14, 15 and 16).

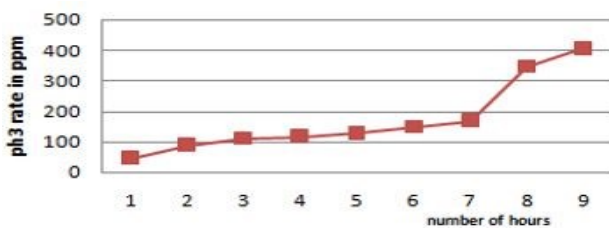


Fig. 14. Variation of the PH3 level inside the laboratory rearing chamber during the first measurement day at a temperature of 25° C

After the closing of the fumigation chamber for one day at 25°C, we performed four repetitions but the results found are not positive. Indeed, we didn't find a total mortality in the larvae of the date moth, where an average corrected mortality is 97.41% and an emergence for the nymphs and eggs of *Ephestia* has an average of corrected mortality equal to 98.4%, whereas total mortality at the adult level of the *Tribolium* reached 100%.

During the 2nd day, we observed a decrease in the PH3 level, which reached 15 ppm after 9 hours of measurement (FIG. 15)

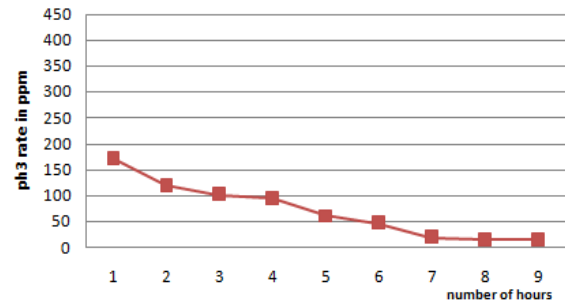


Fig. 15. Variation of the PH3 level inside the laboratory rearing chamber during the 2nd day of measurement at a temperature of 25°C

While during the 3rd day, the PH3 level registered is 0 ppm, (Fig. 16)

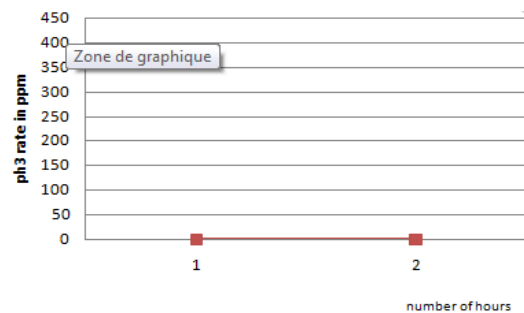


Fig. 16. Variation of the PH3 level inside the laboratory rearing chamber during the 3rd day of PH3 registration amount at a temperature of 25 °C

At a temperature of 35°C, we recorded the evolution of PH3 from the magnesium phosphide plates (ppm) (Figures.17, 18 and 19).

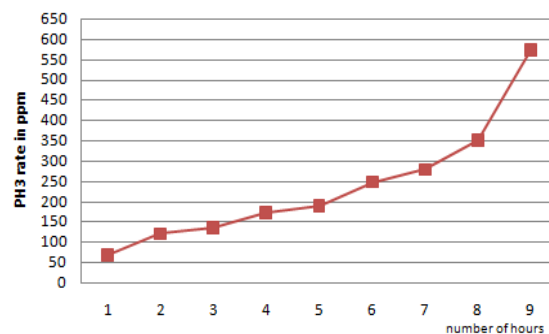


Fig. 17. Variation of the PH3 level inside the laboratory rearing chamber during the first measurement day at a temperature of 35°C

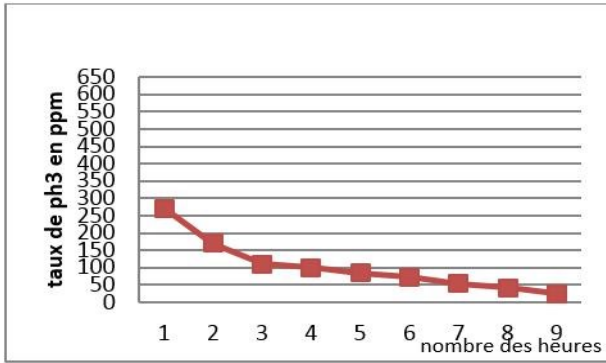


Fig. 18. Variation of the PH3 level inside the laboratory rearing chamber during the second measurement day at a temperature of 35°C

However we noticed a decrease of PH3 level after two hours of recording the gas rate.

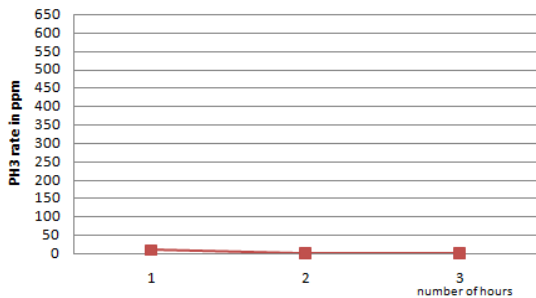


Fig. 19. Variation of the PH3 level inside the laboratory rearing chamber during the third measurement day at a temperature of 35°C

The amount of PH3 emitted from the magnesium phosphide plates reaches its maximum after one day for both temperatures of 25°C and 30°C with a greater phosphine evolution at 35°C. and then a decrease of PH3 during the second day to become zero on the 3rd day of exposure

B. Organoleptic Properties of Treated Date Samples

In order to evaluate the effect of magnesium phosphide tablets at 3g/m³ on the Organoleptic properties of dates: color, odor, taste, texture, water content and total sugar, several samples of dates of Deglet Nour Kebili, Deglet Nour Tozeur, Alig Kebili, Alig Tozeur and Kentichi were analyzed to compare these properties of these treated and untreated dates(control).

The determination of water content and total sugars took place in the laboratory of entomology in National institute of agronomy of Tunisia. The other analyses were carried out in the CTAA (laboratory of the Technical Center of Agro-Food of Tunisia) and others took.

1. At 25°C Temperature

At a temperature of 25°C, Organoleptic properties were analyzed for the 3g/m³ dose and dates. The results were found to be very promising, there was no modifications registered in any parameter (odor, color, taste or texture) of the treated dates of the different varieties compared to the controls (Tab 6)

Table 6. Organoleptic properties of date samples treated and untreated with magnesium phosphide plates at a temperature of 25°C for two days

| Before treatment | | | | Varieties of dates | After treatment | | | |
|------------------|--------|--------|---------|--------------------|-----------------|--------|--------|---------|
| Smell | colour | Taste | Texture | | Smell | Colour | Taste | Texture |
| Normal | Normal | Normal | Normal | Deglet Nour Kebili | normal | normal | normal | normal |
| Normal | Normal | Normal | Normal | Deglet Nour Tozeur | normal | normal | normal | normal |
| Normal | Normal | Normal | Normal | Aligie Kebili | normal | normal | normal | normal |
| Normal | Normal | Normal | Normal | Aligie Tozeur | normal | normal | normal | normal |
| Normal | Normal | Normal | Normal | Kentichi | normal | normal | normal | normal |

Table 7. Water content at 25°C for dates before and after treatment

| doses | before treatment | After treatment |
|-----------|------------------|-----------------|
| 3g | 312,71 | 311,24 |
| 3g/2 days | 315,6 | 313,4 |

Table 8. Total sugar content at a temperature of 25°C

| doses | Before treatment | After treatment |
|---------|------------------|-----------------|
| 3g/1day | 46,94 | 44,7 |

Comparing the results before and after PH3 treatment (tables 6, 7 and 8); we noticed that there were no modifications found in the organoleptic characteristics of the different tested varieties of dates in 25°C.

2. At 35°C Temperature

At a temperature of 35°C, Organoleptic properties were analyzed for the 3g/m³ dose and after one day exposure to phosphine. We found no significant result, that means, the treatment of dates with Digest Plate had no effect on the smell, color, taste and texture of the dates (tab.9)

Table 9. Organoleptic properties of control and treated date samples with phosphine plates at a temperature of 35°C for one day.

| Before treatment | | | | dates varieties | After treatment | | | |
|------------------|--------|--------|---------|--------------------|-----------------|---------|--------|---------|
| Smell | Colour | Taste | Texture | | Smell | couleur | goût | texture |
| normal | normal | normal | normal | Deglet Nour Kebili | normal | normal | normal | normal |
| normal | normal | normal | normal | Deglet Nour Tozeur | normal | normal | normal | normal |
| normal | normal | normal | normal | Aligie Kebili | normal | normal | normal | normal |
| normal | normal | normal | normal | Aligie Tozeur | normal | normal | normal | normal |
| normal | normal | normal | normal | Kentichi | normal | normal | normal | normal |

Table 10. Water content at 25°C for dates before and after treatment

| doses | Before treatment | After treatment |
|-----------|------------------|-----------------|
| 3g/ 1 day | 308,22 | 306,17 |
| 3g/2 days | 323,46 | 319,51 |
| 2g/2 days | 319,55 | 319,46 |
| 1g/2 days | 316,13 | 312,17 |
| 1g/3 days | 316,52 | 314,79 |

Table 11: Total sugar content at a temperature of 25° C

| Doses | Before treatment | After treatment |
|-----------|------------------|-----------------|
| 3g/ 1 day | 44,99 | 42,73 |
| 1g/2days | 47,36 | 48,5 |
| 2g/2 days | 44,65 | 44,39 |
| 2g/3 days | 47,91 | 48,39 |

Comparing the results before and after PH3 treatment (tables 9, 10 and 11); we noticed that there were no modifications found in the organoleptic characteristics of the different tested varieties of dates in 35°C.

C. Analyses of the PH3 Residues on Treated Dates with the Convenient Doses During the Best Exposure Time at 25 and 35°C

Comparing the residues results before and after PH3 treatment, we notice that there was nothing abnormal or extra product was found on treated dates at 25°C as well as 35°C (Tab 12 and 13)

Table 12. Residues content of control and treated date samples with magnesium phosphide plates at a temperature of 25°C for one day.

| Before treatment | Variety of dates | after treatment |
|---------------------------|--------------------|---------------------------|
| Residues analysis results | | Residues analysis results |
| <LD=0,3 ppm | Deqlet Nour Kebili | <LD=0,3 ppm |
| <LD=0,3 ppm | Deqlet Nour Tozeur | <LD=0,3 ppm |
| <LD=0,3 ppm | Aligue Kebili | <LD=0,3 ppm |
| <LD=0,3 ppm | Aligue Tozeur | <LD=0,3 ppm |
| <LD=0,3 ppm | Kenticha | <LD=0,3 ppm |

Table 13. Residues content of control and treated date samples with phosphine plates at a temperature of 35°C for one day.

| Before treatment | Variety of dates | after treatment |
|---------------------------|--------------------|---------------------------|
| Residues analysis results | | Residues analysis results |
| <LD=0,3 ppm | Deqlet Nour Kebili | <LD=0,3 ppm |
| <LD=0,3 ppm | Deqlet Nour Tozeur | <LD=0,3 ppm |
| <LD=0,3 ppm | Aligue Kebili | <LD=0,3 ppm |
| <LD=0,3 ppm | Aligue Tozeur | <LD=0,3 ppm |
| <LD=0,3 ppm | Kenticha | <LD=0,3 ppm |

IV. CONCLUSION

This study revealed that the treatment with Pellets at 25°C during 1,2,3 days at the dose 3g/m³ gives 100% corrected mortality, but at the temperature 35°C, the doses that allow us to reach a corrected mortality of 100% were 1g/2 days, 2g/2 days, and 3g/1 day. If the minimum duration of exposure is required, the best dose is 3g/m³ but we have to mention that at 35°C, the dose 1g/2 days gave positive results (100% of corrected mortality rate)

Using Degesch Plate in the plant, the study revealed that the treatment of dates with Magnesium phosphide varies with temperature.

At a temperature of 25°C the dates should be exposed two days to have a total corrected mortality of pests. While at a

temperature of 35°C., the duration time was reduced to one day.

As we may have different species of pests in storage date rooms, we found that the standard dose convenient to 100% mortality results is 3g/m³.

Using plates with contact with air, about 30 to 60 minutes and depending on the temperature and humidity conditions, the release of PH3 starts from the Magnesium phosphide plates.

The benefits of using magnesium phosphide plates are as follows:

- The applicator does not expose himself to residues of dust or powder, thus reducing the amount of waste.
- No contamination of dates by fumigant residues.
- No side effects on the quality, flavor, or color of the products processed
- No degradation of the ozone layer, hence compliance with the Montreal Protocol.
- Easy application and simple collection after fumigation
- Higher quality standard.
- Very effective also at lower temperatures but by increasing the exposure time of products to PH3
- All the experiments showed that the maximum gas concentrations were reached within the first 24 hours of our experiments.
- Gas destroys insects at all stages of development, including the resistant stages such as egg and nymph stages.

ACKNOWLEDGMENT

The Authors Thank:

+ Stima Company Tunisia: for providing magtoxin pellet, degesch plate and publication support.

+CCPA Boudjbel: for conducting trials in their fumigation rooms.

+ANPE for providing gas detectors for trials.

REFERENCES

- [1] Ben-Amor, R., Aguayo, E. and de Dolores Miguel-Gomez, M. (2015) 'The competitive advantage of the Tunisian palm date sector in the Mediterranean region', Spanish Journal of Agricultural Research, 13(2), pp. 1–8.
- [2] Gomez, V.S. and Ferry, M. (2005) 'Contrôle biologique des principaux ravageurs en palmeraie: état des connaissances et besoins de recherche Gomez Vives S. et Ferry M. (Biological control of major palm pests: state of knowledge and research needs Gomez Vives S. and Ferry M.)', pp. 44–51.
- [3] Jerraya, A. (1993) 'Rapport de synthèse de l (of synthesis of the) atelier " Lutte biologique dans les oasis (Biological struggle in the oases) "', 182, pp. 181–182.
- [4] Dhouibi, M. H. and Lagha, A. (2015) 'Palm Dates Fumigation in Tunisia : Efficiency of Phosphine and CO2 Mixtures, at Different Temperatures, as an Alternative to Methyl Bromide *', 3(6), pp. 1697–1702.
- [5] Dhouibi, M. and Hermi, N. (2015) 'Efficacy of CO and CO2 treatment to control the stored-date insects, Ephestia kuehniella and Ectomyelois ceratoniae for organic dates production.', International Journal of ..., 3(6), pp. 1737–1743. Available at: <http://www.cabdirect.org/abstracts/20153325099.html>.
- [6] Mahmoudi, H., Hosseininia, G., Azadi, H. and Fatemi, M. (2008) 'Enhancing date palm processing, marketing and pest control through organic culture', Journal of Organic Systems, 3(2), pp.

- 29–39.
- [7] Fields, P. (2006) 'Alternatives to chemical control of stored-product insects in temperate regions', Proceedings of the 9th international working conference on stored product protection, pp. 653–662.
- [8] Hagstrum, D. W., Phillips, T. W. and Cuperus, G. (2012) 'Stored Product Protection', 1(April), p. 350. In proceedings of the 6th International working conference on stored-product protection. April 17-23 1994, Canberra, Australia.
- [9] D.K.Mueller. A new method of using low levels of phosphine in combination with heat and carbon dioxide. stored-product protection, (pp. 123-125).
- [10] Dhoubi, M. H. (2000) Lutte intégrée pour le protection du palmier dattier (Integrated control for date palm protection). Coollection Science de l'Ingénieur. Centre de publication universitaire.
- [11] Dhoubi, M. H. (2013). Gestion phytosanitaire intégrée des principaux bioagresseurs du palmier dattieret particulièrement les pyrales de dattes (Integrated phytosanitary management of the main pests of the date palm and particularly the date moths) 66 pages, edition 2013 climat pub..
- [12] Dhoubi, . M., Hawari, W., Touil, S., Zouba, A. and Ben Hamida, F (2017) 'Biocontrol of the Carob Moth *Ectomyelois ceratoniae* (Lepidoptera, Pyralidae) in Two Oases in the South of TUNISIA using Mating Disruption with SPLAT EC O', 5(5), pp. 825–830.
- [13] Fields, P. G. and White, N. D. G. (2002) 'Alternatives Tomethyl Bromide Treatments for Stored-Product Andquarantine Insects', Annual review of Entomology, 47, pp. 331–359.
- [14] MBTOC. 1998. Assessment of Alternatives to Methyl Bromide. Nairobi, Kenya: UN Environ. Comm., Ozone Secretariat. 374 pp.
- [15] MBTOC. 1994. Methyl Bromide Technical Options Committee: Assessment of Alternatives to Methyl Bromide. Nairobi, Kenya: UN Environ. Comm., Ozone Secretariat. 304 pp.
- [16] Zaid, A. (Abdelouahhab) and Arias-Jiménez, E. J. (2002) 'Chapter IX: Date Harvesting, Packinghouse Management and Marketing Aspects', Date palm cultivation, p. 292.
- [17] Wang, F., Jayas, D. S., White, N. D. G. and Fields, P. (2009) 'Combined effect of carbon monoxide mixed with carbon dioxide in air on the mortality of stored-grain insects', Journal of Stored Products Research. Elsevier Ltd, 45(4), pp. 247–253.
- [18] Zouba, A., A. De, Khouldia, O., Régional, C., Diaferia, A., Rosito, V., Olivetti, V. a, Ba, M., Bouabidi, H., Oasienne, A. and Chermiti, B. (2009) 'Microwave Treatment for Postharvest Control of the Date Moth *Ectomyelois ceratoniae*', 4(2), pp. 173–184.
- [19] Cardoso, L., Bartosik, R. and Milanesio, D. (2009) 'Phosphine Concentration Change During Fumigation In Hermetic Plastic Bags (Silobags)', pp. 1–4.