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Insecticidal efficacy of two pirimiphos-methyl formulations for the control of three stored-product beetle species: Effect of commodity

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ABSTRACT

Laboratory bioassays were conducted to evaluate the insecticidal effect of two pirimiphos-methyl formulations, an emulsifiable concentrate (EC) and a capsule suspension (CS) against adults of *Sitophilus oryzae*, *Rhyzopertha dominica* and *Tribolium confusum* in wheat, maize and rice. Pirimiphos-methyl was applied at two dose rates, 2 and 4 ppm, and adult mortality was measured after 2, 7, 14 and 21 days of exposure in the treated commodity. Progeny production was assessed 65 d after the removal of the parental adults. *S. oryzae* adult survival was significantly higher in rice than in wheat and maize, whereas *T. confusum* mortality was significantly higher in maize than in the other grains. From the species tested, the most susceptible species was *S. oryzae*, for which mortality reached 100% after 7 days of exposure in treated wheat and maize, followed by *T. confusum* and *R. dominica*. Progeny production was significantly suppressed by pirimiphos-methyl in the case of *S. oryzae*, but not in the case of *R. dominica*. In general, only few differences in performance between the EC and the CS formulation were detected. We conclude that the type of grain commodity significantly affects mortality after the application of the two pirimiphos-methyl formulations tested, but this effect is species-dependent.

1. Introduction

The rice weevil, *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae), and the lesser grain borer, *Rhyzopertha dominica* (F.) (Coleoptera: Bostrychidae), are considered among the most economically important insect pests of stored cereals globally (Aitken, 1975; Edde, 2012). As internal feeders, both species have the ability to cause great quantitative and qualitative losses in unbroken grain seeds (Hagstrum and Subramanyam, 2006). Larvae feed into the kernels, where they remain until pupation and emergence to the adult stage, being in this way protected and not much affected by the insecticides which are applied to the external kernel part. The confused flour beetle, *Tribolium confusum* Jacquelin du Val (Coleoptera: Tenebrionidae), is an external feeder and one of the most important insect pests of durable food processing and storage facilities, especially in amylaceous commodities.

Pirimiphos-methyl, a broad spectrum organophosphorous contact insecticide, is a commonly used active ingredient for stored grain protection worldwide (Redlinger et al., 1988). So far, pirimiphos-methyl has been successfully evaluated against a wide variety of stored-product insect pests (Athanassiou et al., 2009; Huang and Subramanyam, 2005; Kljajic and Peric, 2007a, 2007b; Rumbos et al., 2013). In a recent study, the insecticidal efficacy of two pirimiphos-methyl formulations, an emulsifiable concentrate (EC) and a capsule suspension (CS), were evaluated against seven stored-product insect species in grains at different temperature and humidity regimes (Rumbos et al., 2013). In order to understand better the performance of pirimiphos-methyl when formulated in different ways, it is also relevant to study the effects of the product when used in different commodities. It is well known that insecticidal efficacy of grain protectants is highly affected by the commodity (Fang et al., 2002; Kavallieratos et al., 2010, 2011). For example, fipronil is reported to be less effective in paddy rice than in barley, maize and wheat (Kavallieratos et al., 2010). Similarly, the performance of spinosad varied among different classes of wheat (Fang et al., 2002).

Encapsulation of insecticides provides some important benefits, such as slow release, potentially leading to an extended residual activity, as well as less risk for non-target organisms and the

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applicator (Perrin, 2000). CS formulations have been successfully developed for various insecticides (Kocak and Babaroglu, 2006; Hubert et al., 2007; Sahu et al., 2008), including pirimiphos-methyl (Rumbos et al., 2013, 2014; WHO, 2013). The objective of the current study was to evaluate the efficacy of two pirimiphos-methyl formulations, an emulsifiable concentrate (EC) and a capsule suspension (CS), in wheat, maize and rice against *S. oryzae*, *R. dominica* and *T. confusum*. Progeny production of the tested species after exposure to the pirimiphos-methyl treated commodities was also assessed.

2. Materials and methods

2.1. Test insects

All species were reared at the Laboratory of Entomology and Agricultural Zoology (Volos, Magnesia, Greece) at 25 °C, 65% relative humidity (r.h.) and continuous darkness. The used insect populations were originally collected from storage facilities in Greece between 2009 and 2011 and were since then continuously cultured in the laboratory. From the species tested, *S. oryzae* and *R. dominica* were reared on whole wheat kernels, while *T. confusum* individuals were reared on wheat flour. Adult beetles < 1-month-old were used in the tests.

2.2. Commodity and insecticide treatment

Untreated, clean and infestation-free durum wheat (variety Simeto), maize (hybrid Dias) or rice (variety Thaibonnet) with very little dockage (<0.1%) were used in the tests. Before the experiment, the commodities were kept in cold storage at −20 °C for at least two weeks. The moisture content of the commodities, as determined by a Multitest moisture meter (Multitest, Gode SAS, Le Catelet, France) after the removal from the cold room was 13.5%. All commodities were taken from the 2011 Greek harvest.

The pirimiphos-methyl formulations tested were Actellic 50 EC (48% AI) and Actellic 300 CS (30% AI) and were obtained from Syngenta International AG (Basel, Switzerland). The insecticides were applied on the grains by using a Kyoto BD-183K airbrush (Grapho-tech, Japan) at a pressure of 2.2 bar, in order to spray at the different rates (see below), using a total volume rate of 1 ml of spraying solution per kg of grain. Spraying was carried out separately for each commodity from a distance of approximately 20 cm on a tray on which grain kernels were spread in a thin layer.

2.3. Bioassays

Lots of 1 kg of wheat, maize or rice were sprayed with the two pirimiphos-methyl formulations at two dose rates, 2 and 4 ppm. The EC formulation label rate is higher than the tested rates, while there is no registration so far for the CS for direct application on grains. An additional series of lots was sprayed with distilled water and used as control. Then, the grains were placed in a glass jar and shaken manually to achieve equal distribution of the insecticide in the entire grain mass.

Plastic cylindrical vials (3 cm in diameter, 8 cm in height) were the experimental units for the tests. The top one quarter of the inside of each vial was covered by polytetrafluoroethylene dispersion (Sigma–Aldrich Co., Germany) to prevent insects from escaping. Each vial was filled with 20 g of wheat, maize or rice, with separate vials for each commodity. Then, twenty adult beetles of mixed sex were placed in each vial, with separate vials for each species. All vials were then placed at 25 °C, 65% r.h. and continuous darkness. Mortality of the exposed individuals was assessed after 2, 7, 14 and 21 days for all beetle species. Each test (three-vials replicate for each dose-formulation-commodity-species combination) was repeated three times (3 series of vials) by preparing different lots of treated and untreated grains each time (3 × 3 vials for each treatment). After the final mortality count, all adults (dead and alive) were removed from the vials, and the vials were left in the incubators for an additional period of 65 days, at the same conditions as above. After the termination of this interval, the emerged adults in each vial were counted. This procedure was followed for all beetle species. However, progeny production of the confused flour beetle was low and did not exceed 1 adult/vial, because, as an external feeder, *T. confusum* cannot develop easily in sound grain kernels. Therefore, no progeny production comparisons among dose rates, formulations and commodities could be made.

2.4. Data analysis

Control mortality was corrected as suggested by Abbott (1925). Since the same vials were examined for mortality after 2, 7, 14 and 21 days, the mortality data were analyzed by using a repeated measures ANOVA with exposure as the repeated measures variable and dose rate, formulation and commodity as the main effects using the JPM 7 software (SAS Institute Inc., Cary, North Carolina, USA). For each exposure interval and within each commodity, the mortality data were submitted to ANOVA to determine differences among treatments. Furthermore, for each exposure interval and within each formulation and dose, the mortality data were submitted to ANOVA to determine differences among commodities. Progeny production counts were submitted to a three-way ANOVA, with offspring numbers as the response variable and dose rate, formulation and commodity as the main effects. Means were separated using the Tukey HSD test at the 5% level (Zar, 1999).

3. Results

3.1. S. oryzae

Mortality of *S. oryzae* adults was significantly affected by the exposure interval, the dose rate, the formulation and the commodity (Table 1). With few exceptions, mortality counts were significantly lower in rice than in wheat and maize (Table 2). Mortality of *S. oryzae* adults reached 100% almost in all cases 7 days after treatment when beetles were exposed to treated wheat and maize, regardless of the dose rate and formulation, whereas, with few exceptions, no significant differences were recorded between the efficacy of the two pirimiphos-methyl formulations at each exposure interval, dose rate and formulation (Table 2). In contrast, for rice, CS provided significantly better control than EC, for which mortality counts reached 42 and 76% at the low and high dose rate respectively, after 21 days of exposure (Table 2).

Progeny counts of *S. oryzae* were significantly affected by dose rate and commodity, but not by formulation and most associated interactions (Table 3). Mean progeny production of *S. oryzae* was 72, 18 and 14 weevils/vial in untreated wheat, maize and rice, respectively, but the differences in progeny counts were not significant due to high variation in progeny numbers (Table 4). In vials containing treated commodities the emergence of *S. oryzae* adults was, with few exceptions, significantly decreased in comparison to the control vials, and ranged between 0 and 0.3 adults/vial for wheat and maize (Table 4). In contract, progeny production on treated rice was notably higher in comparison with wheat or maize, especially in the lowest dose of EC.