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Persistence and efficacy of indoxacarb against three stored product insect species on wheat and maize

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ABSTRACT

In the present study, we investigated the insecticidal efficacy of indoxacarb on wheat and maize, against adults of three major stored-grain species, the rice weevil, *Sitophilius oryzae* (L.) (Coleoptera: Curculionidae), the lesser grain borer, *Rhyzopertha dominica* (F.) (Coleoptera: Bostrychidae) and the confused flour beetle, *Tribollium confusum* Jacquelin Du Val (Coleoptera). For this purpose, bioassays were carried out with indoxacarb at the doses 0.1, 1 and 10 ppm. Moreover, the treated grains were left at the laboratory for a period of six months, in order to examine the residual effect of indoxacarb, by conducting bioassays at monthly intervals. For *S. oryzae* and *R. dominica*, adults were exposed in the treated grains for 7 and 14 d, while for *T. confusum* adults were exposed for 14 and 21 d, in order to estimate the mortality level. After the termination of this interval, the treated samples were left for an additional period of 65 days, on which progeny production was recorded. *R. dominica* was by far more susceptible than *S. oryzae*, given that mortality, in many cases, reached 100% even after 7 d of exposure, even at the lowest dose rate of 0.1 ppm. At the same time, for this species, progeny production was low. For *S. oryzae*, mortality was low at 0.1 ppm, with high levels of progeny production. *T. confusum* was the least susceptible of the species tested. Generally, during the experimental period, the efficacy of indoxacarb was decreased, but mortality was higher on wheat than on maize. Indoxacarb residues determination by GC-ECD indicated that after 6 months 33% of the insecticide remains in grains at 0.1 ppm dose, about 40–50% at 1 ppm and about 40–60% at 10 ppm dose. Based on the results of the present work, indoxacarb is an effective grain protectant, at least in the case of *R. dominica* and *S. oryzae.*

1. Introduction

The development of resistance by many stored-product insect species to some of the currently used grain protectants, necessitates the evaluation of newer substances to be used as alternatives. Resistance is not only connected with the traditional contact neurotoxic insecticides such as organophosphorous compounds (OPs) and pyrethroids, but also to newer, non-neurotoxic substances such as insect growth regulators (IGRs) (Collins, 1990; Collins et al., 1993; Arthur, 1996; Guedes et al., 1996; Daglish, 2008). Several researchers have evaluated with success spinosad, which is based on bacterial metabolites of the actinomycete *Sacharopolyspora spinosa* Mertz and Yao (Bacteria: Actinobacteridae), which is very effective against the lesser grain borer, *Rhyzopertha dominica* (F.) (Coleoptera: Bostrychidae), but moderately effective against the rice weevil, *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) and the confused flour beetle, *Tribolium confusum* Jacquelin Du Val (Coleoptera: Tenebrionidae). Diatomaceous earths (DEs), which are very effective against a wide range of species are recommended; despite the fact that the application of DEs affects negatively the bulk density of the grain (Korunic, 1998; Fields and Korunic, 2000). Finally, IGRs are promising non-toxic alternatives, but their efficacy against *S. oryzae* is not very high, due to the fact that the adult female oviposits inside the kernel, and immature development is not affected by contact insecticides that occur to the external part of the kernel (Arthur, 1996).

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Another substance that is in use against several field pests, is the oxadiazine indoxacarb. Indoxacarb has low mammalian toxicity and is very effective against a wide range of insect species, such as the corn earworm, *Helicovera zea* (Boddie) (Lepidoptera: Noctuidae) and the codling moth *Cydia pomonella* (L.) (Lepidoptera: Torticidae), *Empoasa fabae* (Harris) (Homoptera: Cicadelidae) and the egyptian alfalfa weevil, *Hypera brunnipennis* (Boh.) (Coleoptera: Curculionidae) (Wing et al., 2000; Cardwell et al., 2005). While, persistence on grain is maybe a "red flag" in the case of traditional protectants, residual effect of a low-toxicity compound is a desirable characteristic since it is directly connected with long-term protection. Nevertheless, apart from persistence, it is necessary to develop a detection method on grains, in order to detect possible residues, but also the insecticide dissipation as a function of time. Daglish and Nayak (2011) evaluated indoxacarb on wheat, and found that this compound was effective at 5 ppm against *R. dominica* and *S. oryzae*. However, there are no data available for the persistence of indoxacarb on wheat. In the present work, we evaluated the insecticidal and the residual effect of indoxacarb on wheat and maize, for a storage period of 6 months against *R. dominica, S. oryzae* and *T. confusum.* At the same time, we developed a method for indoxacarb residues determination on grain.

2. Materials and methods

2.1. Insects

The *R. dominica* and *S. oryzae* individuals used in the tests had been reared on wheat, at 25 °C, 65% relative humidity (RH) and continuous darkness, while the *T. confusum* individuals had been reared on wheat flour at the same conditions. Only adults were used in the tests.

2.2. Commodities and insecticide

Hard wheat (var. Simeto) and maize (hybrid Constantsa) that were used in the tests originated from the 2009 harvest in the area of Thessaly (central Greece). The moisture content of both commodities, as determined by a Multitest moisture meter (GODE Co., France) ranged between 11.4 and 11.8%. Before the beginning of the experiments, the required quantities of the grains were stored at ambient conditions for approx. 2 months. The insecticide formulation tested was Stewart 30 WG (Du Pont, Greece), that contains 30% of indoxacarb (w/w) as wettable granules (WG).

2.3. Bioassays

Indoxacarb was tested at four dose rates 0 (control), 0.1, 1 and 10 ppm, corresponding to 0, 0.1, 1 and 10 mg of AI/kg of grain. Four kilogram lots of each grain were sprayed for each dose-commodity combination, by using a Mecafer AG4 artist's airbrush (Mecafer Co., France). The required dose rates were applied with 1 mL of water per kg (4 mL of water per lot), while controls were sprayed only with water. After spraying, the lots were placed individually in glass jars (27 cm in height, 16.5 cm in diameter), shaken manually for 1 min to achieve equal distribution of the insecticide in the entire grain mass, and placed at 25 °C, 65% RH and continuous darkness. Then, from each lot, four samples, of 20 g each, were taken, and each sample was placed in a cylindrical plastic vial (8 cm in height, 3 cm in diameter). On each vial, 20 adults of each species were placed (different vials for each species), and all vials remained at the conditions described above. In the case of *R. dominica* and *S. oryzae* mortality was recorded after 7 and 14 d of exposure, while for *T. confusum* after 14 and 21 d of exposure. After the last mortality count, all adults, dead or alive, were removed and the vials remained at the same conditions for an additional period of 65 d. Then, the vials were opened and checked for progeny production. In the case of *R. dominica* and *S. oryzae* only adult progeny were found, given that immature development occurs within the grain kernels, while for *T. confusum* larvae and pupae were also found (Aitken, 1975). Hence, for the latter species, given that most of the progeny production was at the larval stage (>70%), the number of progeny was merged and considered as "larvae". The same procedure was repeated at 30 d intervals, until the completion of 6

Table 1
ANOVA parameters for main effects and interactions for mortality counts and progeny production of *R. dominica* (total df = 383).

Source	df	F	P
7 Days of exposure			
Dose	3	350.7	<0.01
Commodity	1	22.2	<0.01
Bioassay	5	20.4	<0.01
Dose X Commodity	3	1.8	0.14
Dose X Bioassay	15	3.3	<0.01
Commodity X Bioassay	5	6.2	<0.01
Dose X Commodity X Bioassay	15	1.8	0.04
14 Days of exposure			
Dose	3	283.7	<0.01
Commodity	1	21.9	<0.01
Bioassay	5	12.9	<0.01
Dose X Commodity	3	8.9	<0.01
Dose X Bioassay	15	3.3	<0.01
Commodity X Bioassay	5	6.4	<0.01
Dose X Bioassay X Commodity	15	4.2	<0.01
Progeny production			
Dose	3	119.8	<0.01
Commodity	1	2.1	0.14
Bioassay	5	5.3	<0.01
Dose X Commodity	3	0.9	0.40
Dose X Bioassay	15	3.9	<0.01
Commodity X Bioassay	5	9.3	<0.01
Dose X Bioassay X Commodity	15	4.4	<0.01