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SPINOSAD AND SPINETORAM COMPATIBILITY WITH COMMERCIAL BIOLOGICAL CONTROL AGENTS AND USE IN INTEGRATED PEST MANAGEMENT PROGRAMS

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INTEGRATION ET COMPATIBILITE DU SPINOSAD ET DU SPINETORAM DANS LES PROGRAMMES DE LUTTE INTEGREE

RÉSUMÉ

Des études dans des serres ont été menées pour évaluer la compatibilité du produit SUCCESS4™(ingrédient actif spinosad) et Exalt™ouDelegate™(ingrédient actif spinétorame) dans les programmes de luttes intégrées utilisant des arthropodes utiles.
Le spinosad et le spinétorame se sont avérés avoir un effet pour une gamme d'espèces d'acariens prédateurs. Les deuxsubstances ont cependant montré une très courte persistance des effetsoffrant des possibilités d'utilisations compatibles dans les programmes de lutte intégrée où les acariens prédateurs jouent un rôle important dans le contrôle des populations de ravageurs.
Les effets du spinosad et du spinétorame sur une gamme d'insectes prédateurs importants variaientde neutre à faiblement toxique et les produits à base de spinosad ou de spinétorame peuvent donc être également utilisés sans restriction d'utilisation limitations sur les prédateurs considérés comme les plus importants.
Le spinosad et le spinétorame étaient généralement toxiques pour les parasitoïdes adultes, mais avec une courte persistance des effets. Les deux substancesn'ont cependant montré aucun ou peu d'effet sur les larves de parasitoïdes, bien cachés et protégés au sein de leurs hôtes. Cela indique la compatibilité avec les programmes de lutte intégrée où ces espèces sont importantes à condition qu'une certaine prudence soit exercée pour les introduire après un nombre de jours approprié après l'application de Tracer, Delegate ou Exalt.
Mots-clés : spinosynes, spinosad, spinoteram, effets secondaires, programme de lutte intégrée

ABSTRACT

Semi-field studies in glasshouses were conducted to assess the compatibility of SUCCESS4™(active ingredient spinosad) andExalt™orDelegate ™ (active ingredient spinetoram) in IPM programmes using beneficial arthropods. Both spinosad and spinetoram were found to be harmful to a range of predatory mite species. Both howevershowed a very short persistence of effects, offering opportunities for compatible uses in IPM programmes where predatory mites play an important role in controlling pest populations. The effects of spinosad and spinetoram on a range of important predatory insects varied from being harmless to slightly harmful, and products based on spinosad or spinetoram can therefore be used in IPM programmes without limitations where these predators are considered important. Spinosad and spinetoram were generally harmful for adult parasitoids, but with a short persistence of effects. Both compounds however showed no or only a small effect on larvae of parasitoids, well-hidden and protected within their hosts. This indicates compatibility with IPM programmes where these species are important provided some caution is exercised to introduce the beneficialsat the appropriate number of days after application of Tracer, Delegate or Exalt.
Keywords: spinosynes, spinosad, spinoteram, side-effects, integrated pest management

Introduction

Both spinosad and spinetoram belong to the nicotinic acetylchlorine receptor (nAChR) allosteric modulators (IRAC mode of action group 5). They are produced by fermentation of the naturally occurring bacteria *Saccharopolyspora spinosa*.

Spinosad is a mixture of spinosyn A and spinosyn D. This product is also registered for use in organic farming and has been in the market for many years.

Spinetoram contains a mixture of spinosyn J and spinosyn L. This product has been recently introduced in Europe. It is used to control many economically important pests like pear psylla, different species of thrips, codling moth, leaf miners and other caterpillar species.

In many of the crops where spinosad or spinetoram are used, biological control agents are widely used, or natural populations are encouraged to provide additional control of pests in IPM programmes. Therefore, knowing the toxicity of these spinosyns on beneficial organisms is very important.

Pesticide effects may be direct or indirect (sub-lethal effects), and beneficial arthropods can be exposed to them through different routes of exposure (topical, residual and/or oral). Pesticide selectivity depends not only on its physiological or intrinsic toxicity but also on what is called its "ecological toxicity of exposure" which, depends on many factors such as quantity, dose, type of exposure and duration or frequency of the exposure. The physiological selectivity is usually checked by laboratory testing, while semi-field trials can help with the assessment of the ecological toxicity of exposure. In this way, the use of spinosad, spinetoram or any other pesticide may be adapted, if needed, to fit in IPM programmes always within the frames of Good Agricultural Practice.

Therefore, in the present article, several semi-field studies to evaluate the effects of both spinosad and spinetoram on a variety of commercially important beneficial arthropod species are reported. The intention of this paper is to summarise these studies, conducted under semi-field conditions, to draw a profile of spinosad and spinetoram regarding their side-effects on beneficial organisms and facilitate their use in IPM programmes by choosing the most appropriate timing and type of application to minimise any potential impact on beneficial arthropods, whilst at the same time controlling the key pest or pests.

Methods and Results

Several semi-field studies wereconducted by IPM Impact, to assess the IPM compatibility of spinosad and spinetoram under glasshouse conditions in Belgium. A variety of important species were tested from different beneficial arthropod families including Phytoseiidae, Macrochelidae, Anthocoridae, Coccinellidae, Staphylinidae, Aphelinidae, Eulophidae, Braconidae, Syrphidae, Forficulidae and Miridae. In general, the majority of the studies on side-effects are done on a laboratory scale according to testing methods developed by the International Organisation for Biological and Integrated Control (IOBC) working group 'Pesticides and Beneficial Organisms. Under these test methods, beneficials are released on fresh residue of the test compound (Sterk et al. 1999). However, in practice, this has sometimes led to false negatives. For example, while results of trials carried out according to the IOBC protocol were suggesting low or no effect at all, some products turned out to be rather or even very toxic under practical conditions. Also, the opposite has sometimes appeared, i.e. products that turned out to be harmful in the laboratory had hardly any effect in the field. Therefore, IPM Impact (Belgium) developed new test methods, applying the product directly onto established populations, and therefore much closer to field conditions. In the case of residual studies, beneficials were released on residues of different ages, according to the IOBC protocols (Sterk and Kolokytha 2015; Kolokytha and Sterk 2017a,b).

Studies on established populations used a variety of methods depending upon the species tested and these semi-field methods are summarised in Table 1. In all trials, spinosad was used under the trade name Tracer 480 SC,containing 48% active ingredient. In most tests with spinetoram, the liquid SC formulation of Exalt containing 2.5 % active ingredient was tested, and alsoin some trials in comparison to the 25 % wettable granulate (WG) formulation Delegate. The water volume per application was equivalent to 1000L/ha in all cases. The method followed in most of the presented studies for spinosad is comparable to the IOBC method on dry residues, and applications were made under practical conditions where populations of beneficials had already been established. For spinoteram these studies are based on common agricultural and horticultural practice, where pesticide treatments are usually applied to the existing population of beneficials. The estimated percent mortality of the predators and the reduction in hatching or parasitation were classifiedaccording to the IOBC classes for semi-field trials, where 1 = harmless (<25 %), 2 = slightly toxic (26-50 %), 3 = moderately toxic (51-75 %), 4 = harmful (>75 %).

Table I: Methodology and Results for Spinosad and SpinetoramBeneficial Arthropod Studies in Semi-field Trials, Conducted by IPM Impact-Belgium

Order: Family, Species	Stage exposed, Release method	Condition & Number of applications	Crop	Type of exposure	Compound and Dose rate	Toxic standard, rate and effect (mortality or hatching/ parasitation decrease)	Spinosyn effect (mortality or hatching/ parasitation decrease	IOBC toxicity classification 3-13 days after application	IOBC toxicity classification 14-28 days after application
Predatory mites									
Acari: Phytoseiidae									
Amblyseius californicus	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	Dry residues	Tracer 192 g a.i./ha	Bifenthrin 80 g a.i./ha 100% mortality	27 % mortality 6 days after application	2	
Amblyseius californicus	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	On existing population	Tracer 192 g a.i./ha	Bifenthrin 80 g a.i./ha 100% mortality	54 % mortality 7 days after application	3	
Amblyseius californicus	All (mobile stages) Breeding system	Glasshouse 1 application	Sweet Pepper	On existing population	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	69 % mortality 28 days after application		3
Amblyseius montdorensis	All (mobile stages) Breeding system	Glasshouse 1 application	Sweet Pepper	On existing population	Tracer 192 g a.i./ha	Deltamethrin 80 g a.i./ha 100% mortality	33 % mortality 19 days after application		2
Amblyseius montdorensis	All (mobile stages) Breeding system	Glasshouse 3 treatments	Sweet Pepper	On existing population	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	86 % mortality 14 days after the 3rd application		4
Amblyseius montdorensis	All (mobile stages) Breeding system	Glasshouse 2 applications	Sweet Pepper	On existing population	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	73 % mortality 3 days after the 2nd application	3	
Amblyseius swirskii	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	Dry residue	Tracer 192 g a.i./ha	Bifenthrin 80 g a.i./ha 100% mortality	99 % mortality 7 days after application	4	
Amblyseius swirskii	All (mobile	Glasshouse	Sweet	On existing	Tracer	Lambda	100 % mortality	4	

	stages) Sprinkling	1 application	Pepper	population	36 g a.i./ha	cyhalothrine 100 g a.i./ha 100% mortality	6 days after application		
Amblyseius swirskii	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	On existing population	Tracer 42 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	100 % mortality 6 days after application	4	
Amblyseius swirskii	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	On existing population	Tracer 62 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	100 % mortality 6 days after application	4	
Amblyseius swirskii	All (mobile stages) Breeding system	Glasshouse 1 application	Sweet Pepper	On existing population	Tracer 36 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	0% mortality 8 days after application	1	
Amblyseius swirskii	All (mobile stages) Breeding system	Glasshouse 1 application	Sweet Pepper	On existing population	Tracer 42 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	6 % mortality 8 days after application	1	
Amblyseius swirskii	All (mobile stages) Breeding system	Glasshouse 1 application	Sweet Pepper	On existing population	Tracer 62 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	4% mortality 8 days after application	1	
Amblyseius swirskii	All (mobile stages) Breeding system	Glasshouse 1 application	Sweet Pepper	On existing population	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	100 % mortality 7 days after application	4	
Amblyseius swirskii	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	Residual trial, release 3 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 86% mortality	22 % mortality on 3 days old residue at 8 days after release	1	
Amblyseius swirskii	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	Residual trial, release 7 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 74% mortality	18 % mortality on 7 days old residue at 8 days after release	1	
Amblyseius swirskii	All (mobile	Glasshouse	Sweet	Residual trial,	Exalt	Lambda	0 % mortality on		1

	stages) Sprinkling	1 application	Pepper	release 14 days after application	60 g a.i./ha	cyhalothrine 100 g a.i./ha 80% mortality	14 days old residue at 8days after release		
Phytoseiulus persimilis	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	Dry residue	Tracer 192 g a.i./ha	Deltamethrin 80 g a.i./ha 100% mortality	42% mortality 7 days after application	2	
Phytoseiulus persimilis	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	On existing population	Tracer 192 g a.i./ha	Deltamethrin 80 g a.i./ha 100% mortality	80 % mortality 6 days after application	4	
Phytoseiulus persimilis	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	Residual trial, release 3 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	37% mortality on 3 days old residue at 7 days after release	2	
Phytoseiulus persimilis	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	Residual trial, release 7 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	0 % mortality on 7 days old residue at 7 days after release	1	
Phytoseiulus persimilis	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	Residual trial, release 14 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	0%mortality on 14 days old residue at 7 days after release	1	
Acari: Macrochelidae									
Macrochelesrobustulus	All (mobile stages) Sprinkling	Glasshouse 1 application	Soil	On existing population	Delegate 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 95% mortality	47 % mortality at 7 days after application	2	
Predatory insects									
Hemiptera: Anthocoridae									
Orius laevigatus	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	Dry residue	Tracer 96 g a.i./ha	Bifenthrin 80 g a.i./ha 100% mortality	71 % mortality at 6 days after application	3	
Orius laevigatus	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	On existing population	Tracer 36 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	71 % mortality at 6 days after application	3	

Oriuslaevigatus	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	On existing population	Tracer 42 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	73 % mortality at 6 days after application	3	
Oriuslaevigatus	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	On existing population	Tracer 62 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	86 % mortality at 6 days after application	4	
Oriuslaevigatus	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	Residual trial, release 3 days after application	Exalt 60 g a.s./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	53 % mortality on 3 days old residue at 7 days after release	3	
Oriuslaevigatus	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	Residual trial, release 7 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 97% mortality	% mortality on 7 days old residue at 7 days after release	1	
Oriuslaevigatus	All (mobile stages) Sprinkling	Glasshouse 1 application	Sweet Pepper	Residual trial, release 14 days after application	Exalt 60 g a.s./ha	Lambda cyhalothrine 100 g a.i./ha 93% mortality	22% mortality on 14 days old residue at 7days after release	1	
Hemiptera: Miridae									
Nesidiocoris tenuis	All (mobile stages) Existing population	Glasshouse 1 application	Tomato	Residual trial, Beneficial release 3 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	45 % mortality on 3 days old residue at 12 days after release	2	
Nesidiocoris tenuis	All (mobile stages) Existing population	Glasshouse 1 application	Tomato	Residual trial, Beneficial release 7 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	44 % mortality on 7 days old residue at 12 days after release	2	
Nesidiocoris tenuis	All (mobile stages) Existing population	Glasshouse 1 application	Tomato	Residual trial, Beneficial release 14 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	42 % mortality on 14 days old residue at 12days after release	2	

Macrolophus caligino sus	All (mobile stages)	Glasshouse 1 application	Tomato	On existing population	Tracer 192 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	41 % mortality at 13 days after application	2	
Macrolophus caligino sus	All (mobile stages)	Glasshouse 3 treatments	Tomato	On existing population	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	46 % mortality 19 days after the last treatment		2
Coleoptera: Coccinellidae									
Delphastus catalinae	Larvae	Glasshouse 1 application	Sweet pepper	On existing population	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	68 % mortality 7 days after application	3	
Diptera: Cecidomyiidae									
Feltiella acarisuga	Larvae	Glasshouse 1 application	Sweet pepper	On existing population	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	59 % mortality at 13 days after application	3	
Feltiella acarisuga	Larvae	Glasshouse 1 application	Sweet pepper	On existing population	Delegate 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	56 % mortality at 13 days after application	3	
Diptera: Syrphidae									
Episyrphus balteatus	Larvae	Glasshouse 3 applications	Sweet pepper	On existing population	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	44 % mortality 7 days after application	2	
Episyrphusbalteatus	Larvae	Glasshouse 3 applications	Sweet pepper	On existing population	Delegate 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	24 % mortality 7 days after application	1	
Dermaptera: Forficulidae									
Forficulaauricularia	All (mobile stages)	Glasshouse 3 applications	Plain soil	On existing population	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% mortality	40 % mortality 7 days after the third application	2	

				Parasitoid insects					
Hymenoptera: Aphelinidae									
Eretmoceruseremicus	Larvae (in yellow whitefly scales)	Glasshouse 1 application	Tomato	On existing population	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 70% reduction in hatching	23 % reduction in hatching 7 days after application	1	
Eretmoceruseremicus	Adults	Glasshouse 1 application	Tomato	Residual trial, release 14 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 88% reduction in parasitation	0 % reduction in parasitation after 14 days old residue 9 days after release		1
Eretmoceruseremicus	Adults	Glasshouse 1 application	Tomato	Residual trial, release 21 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 80% reduction in parasitation	11 % reduction in parasitation after 21 days old residue 9 days after release		1
Eretmoceruseremicus	Adults	Glasshouse 1 application	Tomato	Residual trial, release 28 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 51% reduction in parasitation	11 % reduction in parasitation after 21 days old residue 9 days after release		1
Encarsiaformosa	Adults IOBC protocol	Glasshouse 1 application	Tomato	Dry residue	Tracer 192 g a.i/ha	Bifenthrin 80 g a.i./ha 100% reduction in parasitation	63 % reduction in parasitation 30 days after application		3
Encarsiaformosa	Larvae (in black whitefly scales)	Glasshouse 1 application	Tomato	On existing population	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 86% reduction in parasitation	34 % reduction in hatching 7 days after application	2	
Encarsiaformosa	Adults	Glasshouse 1 application	Tomato	Residual trial release 14 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 89% reduction in parasitation	0 % reduction in parasitation on 14 days old residue 30 days after release		1

Encarsiaformosa	Adults	Glasshouse 1 application	Tomato	Residual trial release 21 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 84% reduction in parasitation	0 % reduction in parasitation on 21 days old residue 30 days after release		1
Encarsiaformosa	Adults	Glasshouse 1 application	Tomato	Residual trial release 28 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 75% reduction in parasitation	0 % reduction in parasitation on 28 days old residue 30 days after release		1
Hymenoptera: Aphidiidae									
Aphidiuscolemani	Adults IOBC protocol	Glasshouse 1 application	Sweet pepper	On existing population	Tracer 192g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% reduction in parasitation	12% reduction in parasitation 10 days after application	1	
Aphidiuscolemani	Larvae (in mummies)	Glasshouse 1 application	Sweet pepper	On existing population	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./h 89% reduction in hatching	28 % reduction in hatching 10 days after application	2	
Aphidiuscolemani	Larvae (in mummies)	Glasshouse 1 application	Sweet pepper	On existing population	Delegate 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 89% reduction in hatching	31 % reduction in hatching 10 days after application	2	
Aphidiuscolemani	Adults	Glasshouse 1 application	Sweet pepper	Residual trial, Beneficial release 14 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 84% reduction in parasitation	2 % reduction in parasitation on 14 days old residue 25 days after release		1
Aphidiuscolemani	Adults	Glasshouse 1 application	Sweet pepper	Residual trial, Beneficial release 21 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 78% reduction in parasitation	0 % reduction in parasitation on 21 days old residue 25 days after release		1

Aphidiuscolemani	Adults	Glasshouse 1 application	Sweet pepper	Residual trial, Beneficial release 28 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 69% reduction in parasitation	7 % reduction in parasitation on 28 days old residue 25 days after release		1
Hymenoptera: Eulophidae									
Diglyphusisaea	Adults	Glasshouse 1 application	Sweet pepper	On existing population	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% reduction in parasitoid larvae and pupae	76% reduction in number of parasitoid larvae and pupae in leaf mines 11 days after application		4
Diglyphusisaea	Adults	Glasshouse 1 application	Sweet pepper	On existing population	Delegate 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% reduction in parasitoid larvae and pupae	73% reduction in number of parasitoid larvae and pupae in leaf mines, 11 days after application		3
Hymenoptera: Trichogrammatidae									
Trichogrammaevanes cens	Adults	Glasshouse 1 application	Tomato	Residual trial, Beneficial release 14 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 100% reduction in parasitation	21 % reduction in parasitation on 14 days old residue 15 days after release		1
Trichogrammaevanes cens	Adults	Glasshouse 1 application	Tomato	Residual trial, Beneficial release 21 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 99% reduction in parasitation	17 % reduction in parasitation on 21 days old residue 15 days after release		1
Trichogrammaevanes cens	Adults	Glasshouse 1 application	Tomato	Residual trial, Beneficial release 28 days after application	Exalt 60 g a.i./ha	Lambda cyhalothrine 100 g a.i./ha 97% reduction in parasitation	15% reduction in parasitation on 21 days old residue 15 days after release		1

Discussion

This paper provides a large dataset of semi-field studies conducted with spinosad (Tracer) and spinetoram (Exalt, Delegate) against an important range of commercial beneficial arthropods (Table 1).

Mites:the phytoseiid predatory mites *A. californicus, A. montdorensis, A. swirskii and P. persimilis* were tested. Spinosad was found to be toxic for these predatory mites when sprayed on existing populations, according to standard IOBC protocols,but presented only a short persistence of toxicity. Moreover, the toxic effects werereduced within a short time when spinosad was sprayed at the tested dose rates on an established population. According to Table I, the effect of spinosad on the population decreased when a breeding system release method *of A. swirskii* was used. When spinetoram was applied on an established population, at the tested dose rates, high mortality resulted but again a short persistence of adverse effects was recorded. Spinetoram (Exalt and Delegate) was found to be moderately toxic (Class 2) on thesoil dwelling predatory mite *M.robustulus*, with a short persistence of both products. We may conclude that when a sprinkling release system is used or predatory mite populations are established, Spinosad and Spinetoram should not be applied. On the other hand,when a breeding system is used, which is a widespread practice for generalist predatory mites such as *Amblyseius* spp. in greenhouses, the population will recover shortly after treatment and Spinosad is softer than Spinetoram. Also, waiting1 day for Spinosad or 7 days for Spinetoram for the spray residue to dry before releasing the predatory mites through sprinklingon the leaves is a recommended practice to avoid effects. Furthermore, due to the efficacy of spinosad and spinetoram on thrips species, the predator/prey ratio (number of predatory mites compared to the number of insect pests) turns favourable. In that case, the application of spinosad or spinetoram minimises the number of key pests, while the survived predatory beneficials such as *A. swirskii* or *A. montdorensis*, will be able to control the unaffected pest(s) population.

Predatory bugs: The effects of both active ingredients on predatory insects varied from harmless to harmful, with the effects on most species given a rating of slightly to moderately harmful. Still, the effects wereof short duration, as observed in all residual trials. Concerning *O. laevigatus*, spinosad was moderately toxic to harmful (IOBC Classes 3 to 4) for the mobile stages when applied on an established population, but the toxicity decreased after a short time. Similarly, spinetoram showed the same trend on*O. laevigatus*.. We may conclude that when a sprinkling release system is used or *O. laevigatus* populations are established, Spinosad and Spinetoram should not be applied. The recommendation is waiting 1 day for Spinosad or 7 days for Spinetoram for the spray residue to dry before releasing this predator. Then, spinetoram was characterized as slightly toxic for *N. tenuis* and *M. caliginosus* when applied to established populations, so we can conclude that a single application of Spinosad or Spinetoram on established populations of *N. tenuis*and *M. caliginosus* is acceptable.

Other predators, dipterans and parasitic wasps: Concerning the other tested predatory insects, spinetoram (Exalt) was moderately toxic towards the larvae of *D. catalinae* and *F. acarisuga.* Delegate was also moderately toxic for larvae of*F. acarisuga*, indicating that both spinetoram formulations had the same effect on the predatory gall midge. The interval between the application of Spinetoram and the release of *D. catalinae* and *F. acarisuga* in order to be safe is 2 weeks. Exalt was characterized as slightly toxic, while Delegate was harmless for the larvae *E.balteatus* after 3 consecutive applications, so we can conclude that Spinetoram is compatible with this syrphidae.

Exalt was also slightly toxic for the mobile stages of earwig *F. auricularia,* when applied on existing population.On the other hand, when Exalt was applied on the adults of the whitefly parasitoid*E. eremicus*, the toxicity disappeared within 2 weeks. No effects were observed when Exalt was applied on larvae of *E. eremicus*, as they are well-protected inside the scales of whiteflies. Similarly, when Exalt was applied on the larvae of *E. formosa*, also protected inside whitefly's scales, there was hardly any reduction in hatching, while residual activity was rather short. Spinosad caused a moderate decrease in the parasitation of *E. Formosa* even when the adults were released on a dry residue. Spinetoram had no effect on the larvae or mummies of *A. colemani*. Only a slight reduction in the parasitation of adults was observed, while the persistence of spinetoram was low two weeks after application. Spinosad also had a short persistence and caused a minor decrease of the parasitation rate of *A. colemani*, even when the adults were released on dry residues. On the contrary, Exalt was toxic on adults of the leafminer parasite *D. isaea.* No decrease was observed, however, on the parasitation rate of *T. evanescens* if it was released on 14-days old residue. In conclusion, adult parasitic wasps were found to be very sensitive to spinosad and spinetoram, but also in these cases, the residual trials indicated a very short persistence. Furthermore, there was no effect on the protected life stages of parasitoids, such as yellow or black scales of whiteflies or mummies of aphids. Therefore, it can be concluded that both spinosad and spinoteram are harmless for the larvae of parasitoids, hidden and feeding in their hosts. In general, for the parasitoids, the waiting period between application and release should be 2 weeks.

The following table is meant to help the management of spinosyns together with beneficials release in the field.

Table II: nº of days needed between application and beneficial release for compatibility after 1 application foliar of Spinosad and spinetoram

Family	Beneficial	Stage	Spinetoram Nº of days between application and release	Spinosad Nº of days between application and release
Phytoseiidae	*Amblyseius californicus*	Mixed population	1 week	0
	Amblyseius swirskii	Mixed population	1 week	1 day
	Phytoseiulus persimilis	Mixed population	1 week	0
	Amblyseius montdorensis	Mixed population	1week	1 day
Predatory mites	*Macrocheles robustulus*	Mixed population	0	0
Coccinellidae	*Delphastus catalinae*	Mixed population	1 week	0
Miridae	*Macrolophus caliginosus*	Mixed population	0	0
	Nesidiocoris tenuis	Mixed population	0	0
Anthocoridae	*Orius laevigatus*	Mixed population	1 week	1 day
Cecidomyiidae	*Feltiella acarisuga*	Larvae	2 weeks	0
Syrphidae	*Episyrphus balteatus*	Larvae	0	0
Dermaptera	*Forficula auricularia*	Mixed population	0	0
Parasitoids	*Encarsia formosa*	Adults	2 weeks	1 day
		Black scales larvae	0	0
	Eretmocerus eremicus	adult	2 weeks	0
		Larvae	0	0
	Aphidius colemani	Adults	2 weeks	0
		Mummies (larvae)	0	0
		Mummies hatching	0	0
	Diglyphus isaea	Mixed population	1 week	0
	Trichogramma spp	Adults	1 week	1 day

Overall these results indicate compatibility of spinosad and spinetoram with IPM programmes in glasshouses, where these species of beneficial arthropods are considered important, with a caution provided thatseveral species should be introduced a few days after spray application. Beneficials in commercial greenhouses are likely to recover quickly after the application of one of these plant protection products. In the tests no significant differences were found in the responses of beneficial organisms between the WG formulation and SC formulation of spinetoram.

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