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Evaluation of a spinetoram-based insecticide against lepidopteran and thrips infesting acacia and eucalyptus in Sumatra, Indonesia

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Abstract
Feeding by the *Spodoptera exigua* (Hübner, 1818) (Lepidoptera: Noctuidae) and *Scirtothrips* sp. (Thysanoptera: Thripidae) cause damage to *Acacia crassicarpa* A. Cunn. ex Benth. (Fabaceae) plants and these pests are key factors affecting the production in nurseries. Leafroller, *Strepsicrates semicanella* (Walker, 1866) (Lepidoptera: Tortricidae) cause severe damage to young *Eucalyptus* spp. (Myrtaceae) plantations. Use of low-hazard insecticide with the conservation of populations of natural enemies integrates effective management. Nursery and field experiments were conducted in 2018-2019 to evaluate the low-hazard insecticide, spinetoram for control of lepidopteran and thrips. Insecticides were applied in combination with surfactant. A spinetoram-based solution (0.12%) was exceedingly effective for the control of *S. exigua* and thrips in nursery. Effectiveness of spinetoram-based solution (0.12%) was 100% to *S. exigua* and 95% to *Scirtothrips* sp. at 15 days after treatment (DAT). Severity of *Scirtothrips* sp. was 5.3% in the spinetoram (0.12%) treatment while it was 80% in standard check chlorpyrifos (0.4%) and 96% in untreated control at 15 DAT. Spinetoram at 12 g a.i./ha was significantly effective than standard check imidacloprid at 20 g a.i./ha against *S. semicanella* in *Eucalyptus* spp. plantation reducing severity from 58 to 2.8% at 30 DAT. Spinetoram at five, seven and 10 g a.i./ha was on par ($P \leq 0.05\%$) at 10 DAT compared to 2 g a.i./ha and untreated control against *S. semicanella.* Spinetoram has broad insecticidal spectrum activity and reliable indices for integrated pest management strategies against major pests of *A. crassicarpa* and *Eucalyptus* spp.

Keywords: *Acacia*, broad-spectrum insecticide, control, *Eucalyptus*, pest, spinosyn

Introduction
Acacia crassicarpa A. Cunn. ex Benth. (Fabales: Fabaceae) and *Eucalyptus* spp. (Myrtales: Myrtaceae) are the two main genera used in the tropical forest plantations of Indonesia [1, 2]. *Acacia crassicarpa* A. Cunn. ex Benth. and *Acacia mangium* Willd. formed major backbones of paper, pulp and viscose production for at least three decades [3, 4]. The spread of two diseases [*i.e. Ceratocystis* Ellis & Halst. (Microascales: Ceratocystidaceae) and *Ganoderma* P. Karst (Polyporales: Ganodermataceae)] in relation to damage to fauna and by the humid tropical environment has forced a change of planted species from *A. mangium* to *A. crassicarpa* and to *Eucalyptus* spp. related interspecific hybrids [5]. *Acacia* hybrids (*A. mangium* × *Acacia auriculiformis* A. Cunn. ex Benth.) were also planted in recent times especially in Vietnam [6, 7].

Nurseries and plantations with *A. crassicarpa* and *Eucalyptus* spp. experiences insect pest losses despite the best efforts at control [8, 9, 10]. Nursery seedlings of *A. crassicarpa* and *Eucalyptus* spp. are attacked by a large number of insects including aphids such as the cowpea aphid, *Aphis craccivora* C.L. Koch, 1854 and the cotton aphid, *Aphis gossypii* Glover, 1877 (Hemiptera: Aphididae), defoliating caterpillars (Lepidoptera: Erebidae and Noctuidae), fungus gnats (Diptera), green leafhoppers such as *Empoasca* sp. (Hemiptera: Cicadellidae), leafrollers (Lepidoptera: Crambidae and Tortricidae), mealybugs such as the striped mealybug, *Ferrisia* sp. and the long-tailed mealybug, *Pseudococcus* sp. (Hemiptera: Pseudococcidae), mites (Acari: Tetranychidae), sap sucking bugs including *Helopeltis theivora* Waterhouse, 1886 (Hemiptera: Miridae), thrips such as *Scirtothrips* sp. (Thysanoptera: Thripidae), and whiteflies including *Bemisia* sp. (Hemiptera: Aleyrodidae) [11, 12, 13]. Recently the beet armyworm, *Spodoptera exigua* (Hübner, 1818) (Lepidoptera: Noctuidae) and *Scirtothrips* sp.

emerged as major pests in nursery causing economic loss to *Acacia* spp. seedlings [14, 15]. Leafroller comprised by *Strepsicrates semicanella* (Walker, 1866) (Lepidoptera: Tortricidae) and other species and sap sucking bugs such as *Arthriticus eugeniae* Bergroth, 1923, *Helopeltis bradyi* Waterhouse, 1886, *H. theivora*, and *Ragwelellus festivus* (Miller, 1954) (Hemiptera: Miridae) cause serious damage to young *Eucalyptus* spp. plantations [16, 17].

The nursery and field pests of *Acacia* spp. and *Eucalyptus* spp. are mostly managed by insecticides [18]. As most of the forest companies are aligned with Forest Stewardship Council (FSC; Bonn, Germany) polices, there is regulation to use highly hazardous pesticides [19, 20]. Integrated pest management (IPM) highlights to rotate the active ingredients and to use environmentally safer molecules [21]. Spinetoram is a semi-synthetic insecticide developed by Dow AgroSciences LLC [Zionsville, Indiana, United States of America (USA)] and registered under the reduced risk pesticide initiative by the United States Environmental Protection Agency (EPA) (William Jefferson Clinton Federal Building, Washington, D.C., USA) [22, 23]. United States EPA presented spinetoram with a 2008 Green Chemistry Award (Royal Society of Chemistry; Burlington House, London, United Kingdom) in the category of designing greener chemicals [24]. It is a derivative of the biological active substances spinosyns produced by the soil actinomycete *Saccharopolyspora spinosa* Mertz & Yao, 1990 (Actinomycetales: Pseudonocardiaceae) [25, 26]. This compound is characterized by a high safety profile and relatively long persistence [27]. Spinetoram acts through a novel site in the nicotinic receptor that is distinct from neonicotinoids or any other nicotinic actives [28]. Spinetoram activates α6-nAChR triggering cascade of events leading to insect death. This mode of action is effective in controlling a variety of insect pests, belongs to blattodean (e.g. termites), coleopteran, dipteran, hymenopteran (e.g. ants), lepidopteran, and thysanopteran [24, 29].

The objectives of the current study were to test efficacy of a spinetoram-based insecticide against 1) *S. exigua* and *Scirtothrips* sp. in *A. crassicarpa* nursery and 2) leafroller, *S. semicanella* in young *Eucalyptus* spp. plantations.

Materials and methods

Nursery experiments

Insecticides were tested against *S. exigua* and *Scirtothrips* sp. in the nursery of PT. Riau Andalan Pulp and Paper (RAPP) in Pangkalan Kerinci, Riau, Sumatra, Indonesia (0° 23' N × 101° 51' E, 10 m above sea level) during December 2018. Spinetoram available in the brand name Endure 120 SC® from PT. Dow AgroSciences Indonesia (Jakarta, Indonesia) was evaluated for efficacy with standard check chlorpyrifos (class: organophosphate) in brand name Dursban 200 EC® from PT. Dow AgroSciences Indonesia. Sand beds of *A. crassicarpa* mother plants, infested with *S. exigua*, were selected for first set of experiment. One sand bed comprised of 1,500 *A. crassicarpa* mother plants planted. Two sand beds were treated with Endure 120 SC® at 0.12% in combination with surfactant applied at 0.1% v.v^{-1} (Agristick 400 L; a.i.: alkyl aryl polyglycol ether at 400 mL.L^{-1}; PT. Bayer Indonesia, Jakarta, Indonesia) and two sand beds with Dursban 200 EC® at 0.4% in combination with surfactant at 0.1% v.v^{-1}. Two beds were applied with water from a nearby well as control treatment. In each sand bed 25 plants were selected randomly, tagged with red tape and assessed for *S. exigua* infestation. Severity of *S. exigua* was assessed before treatment and two, five, nine, 12, and 15 days after treatment (DAT) based on nursery monitoring schedule. Severity of each labelled plant was measured using the scale: 0= healthy shoots (no fresh injury and living insects), 1= 1-25% of shoots with fresh injury and/or living insects, 2= 26-50% of shoots with fresh injury and/or living insects, and => 50% of shoots with fresh injury and/or living insects. Four shoots from the top were assessed per plant.

In second set of experiment *A. crassicarpa* mother plants in sand beds infested with *Scirtothrips* sp. were selected. A spinetoram-based insecticide was evaluated for efficacy with standard check propoxur 50% + dimehypo 25% (Provost 75 WP®; PT. Mitra Kreasidharma, Jakarta, Indonesia) against *Scirtothrips* sp.. Two sand beds each were treated with Endure 120 SC® at 0.12% and Provost 75 WP® at 0.08% in combination with surfactant at 0.1% v.v^{-1}, respectively. Two beds were applied with water from a nearby well as control treatment. In each sand bed 25 plants were selected randomly, tagged with red tape and assessed for *Scirtothrips* sp. infestation. Insecticide treatments were done using lever-operated manual knapsack sprayer (Alpha 16®; Jakarta, Indonesia). Spray tank capacity was 16 L and pump pressure 2-4 bar (29-58 psi). Nozzle (spray angle 80°, FCX 04, ST. Spray Nozzle, Malaysia) used was solid cone with 2.10 L/min. discharge rate at 2 bar. Total spray solution used for one bed was 4 L in 2.5 min. Severity of *Scirtothrips* sp. was assessed before treatment and one, four, seven, 12, and 15 DAT. Severity of each labelled plant was measured using the scale: 0= healthy shoots (no fresh injury and living insects), 1= 1-25% of shoots with fresh injury and/or living insects, 2= 26-50% of shoots with fresh injury and/or living insects, and => 50% of shoots with fresh injury and/or living insects. Four shoots from the top were assessed per plant.

Severity (%) was calculated according to the following formula: severity= [(0 × number of plants with injury or larva/nymph/adult equal to 0) + (1 × number of plants with injury or larva/nymph/adult equal to 1) + (2 × number of plants with injury or larva/nymph/adult equal to 2) + (3 × number of plants with injury or larva/nymph/adult equal to 3) ÷ (3 × total plants in the plots)] × 100. Formula was used to calculate the effectiveness of treatments with insecticide [(X – Y) ÷ X] × 100. X= the per cent severity in the check and Y= the per cent severity in the treatment beds [30].

Field experiments

Leafroller, *S. semicanella* infested *Eucalyptus* spp. (*Eucalyptus pellita* F. Muell. and *Eucalyptus grandis* W. Hill × *E. pellita*) plantation of age 1.5 months belonging to RAPP in Teso East Sector, Riau, Sumatra, Indonesia (0° 30' N × 101° 26' E, 15 m above sea level) was selected for field trials. In the first experiment, Endure 120 SC® at 12 g a.i./ha was evaluated with the standard check imidacloprid (Confidor 200 SL®; PT. Bayer Indonesia, Jakarta, Indonesia) at 20 g a.i./ha. Control was without any treatment. Treatments were arranged in a randomized block design with 10 replications. Each treatment comprised of 7 × 7 plants in gross plot and 5 × 5 plants in net plot. Spacing betwen the plants was 3 × 2 m (initial stocking of 1,667 trees.ha^{-1}). In second experiment, Endure 120 SC® at two, five, seven, 10, and 12 g a.i. /ha was tested. Control was without any treatment. Treatments were arranged in a randomized block design with five replications. Insecticide treatments were done using lever-operated manual knapsack sprayer (Alpha 16®). Spray solution received per plant in the treatment plots was 61 mL. The assessment of *S. semicanella* infestation was conducted before treatment and 10, 20 and 30 DAT. Presence of *S. semicanella* larva in each plant was classified according to the following scale: 0= healthy shoots (no living larva), 1= less than 25% of shoots with larva, 2= 26-50% of shoots with larva, 3= more than 51-75% of shoots with larva, and 4=< 75% of shoots with larva. All branches were assessed per plant.

Severity (%) was calculated according to the following formula: severity= [(0 × number of plants with larva equal to 0) + (1 × number of plants with larva equal to 1) + (2 × number of plants with larva equal to 2) + (3 × number of plants with larva equal to 3) + (4 × number of plants with larva equal to 4) ÷ (4 × total plants in the plots)] × 100.

Incidence (%) is calculated according to the following formula: incidence= [(number of infested plants) ÷ (total plants in the plots)] × 100.

Statistical analysis

Statistical analysis was performed to determine the effect of treatment on measured parameters by using the analysis of variance (ANOVA) at the level of confidence at 5%. Difference between treatments for each parameter analyzed by the Duncan's new multiple range test (MRT) with a confidence level at 5% if significant difference was detected. Data was analyzed using IBM SPSS® software, version 19 [31].

Results and discussion

Effectiveness of spinoteram against *S. exigua* on *A. crassicarpa* in nursery

Spinetoram has board spectral insecticide property against leafrollers, thrips, whiteflies, and defoliating caterpillars mainly *Spodoptera* [32, 33, 34]. The results from current experiment in nursery suggest that *S. exigua* were highly sensitive to spinetoram at 0.12% than chlorpyrifos at 0.40%. Severity of *S. exigua* was 0% in the spinetoram (0.12%) treated beds while it was 8% in chlorpyrifos (0.40%) and 13% in water treated control at 15 DAT. Spinetoram (0.12%) caused 100% larval mortality at 5 DAT (Figure 1).

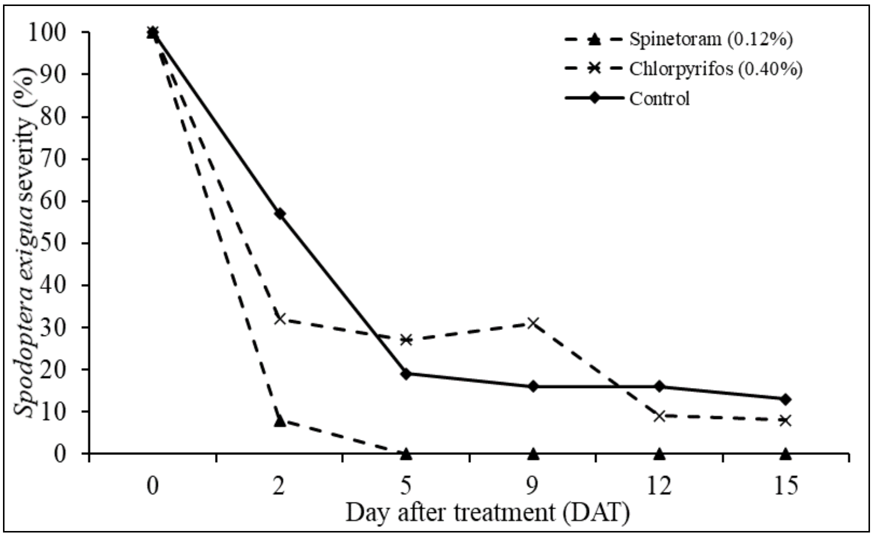

Fig 1: Evaluation of insecticides against *Spodoptera exigua* (Lepidoptera: Noctuidae) on *Acacia crassicarpa* (Fabaceae) in nursery.

Effectiveness of spinetoram was 100% at 5 DAT against *S. exigua* and *S. litura*. It was observed that effectiveness of chlorpyrifos was 92% and water treated control 87% at 15 DAT (Table 1). Operational nursery activity of harvesting *Acacia* shoots during the course of trial may lead to natural reduction of infestation.

Table 1: Effectiveness of insecticides against *Spodoptera exigua* (Lepidoptera: Noctuidae) on *Acacia crassicarpa* (Fabaceae) in nursery.

Treatments	Effectiveness (%)					
	0 DAT	**2 DAT**	**5 DAT**	**9 DAT**	**12 DAT**	**15 DAT**
Spinetoram (0.12%)	0	92	100	100	100	100
Chlorpyrifos (0.40%)	0	68	73	69	91	92
Control (water)	0	43	81	84	84	87

DAT= days after treatment. Abbott (1925) formula= [(X – Y) ÷ X] × 100. X= the per cent severity in the check and Y= the per cent severity in the treatment beds.

Effectiveness of spinoteram against *Scirtothrips* sp. on *A. crassicarpa* in nursery

Spinetoram at 0.12% was extremely effective for the control of *Scirtothrips* sp. in nursery. Severity of *Scirtothrips* sp. was 5.30% in the spinetoram treated beds while it was 80% in chlorpyrifos and 96% in water treated control beds at 15 DAT. Spinetoram caused 100% *Scirtothrips* sp. mortality at 7 DAT (Figure 2).

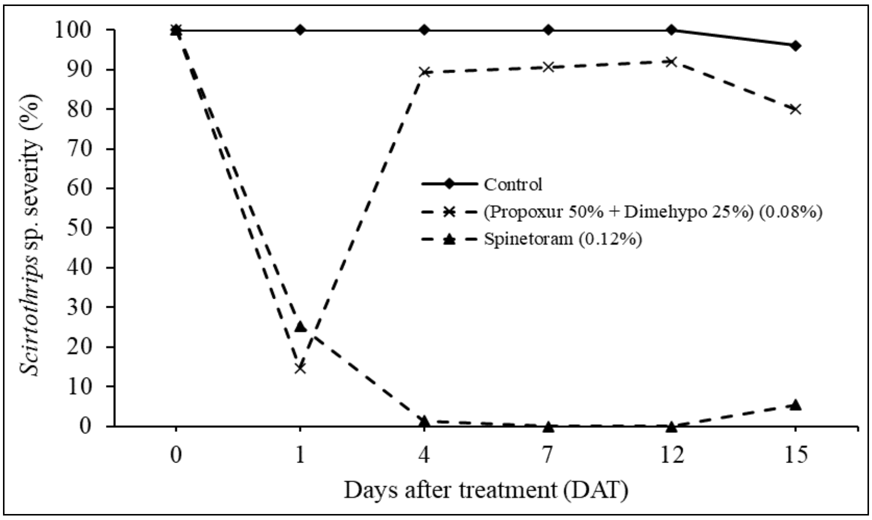

Fig 2: Evaluation of insecticides against *Scirtothrips* sp. (Thysanoptera: Thripidae) on *Acacia crassicarpa* (Fabaceae) in nursery.

Effectiveness of spinetoram was 100% at seven and 12 DAT (Table 2). In addition, it was observed that effectiveness reduced to 95% at 15 DAT. Effectiveness of chlorpyrifos was 20% and water treated control was 4% at 15 DAT.

Table 2: Effectiveness of insecticides against *Scirtothrips* sp. (Thysanoptera: Thripidae) on *Acacia crassicarpa* (Fabaceae) in nursery.

Treatments	Effectiveness (%)					
	0 DAT	1 DAT	4 DAT	7 DAT	12 DAT	15 DAT
Spinetoram (0.12%)	0	75	99	100	100	95
Chlorpyrifos (0.40%)	0	85	11	9	8	20
Control (water)	0	0	0	0	0	4

Abbott (1925) formula= [(X – Y) ÷ X] × 100. X= the per cent severity in the check and Y= the per cent severity in the treatment beds.

Spinetoram at 0.12% has greater utility for *S. exigua* and *Scirtothrips* sp. management in nursery. The results showed that the effectiveness of spinetoram was 100% to *S. exigua* and 95% to *Scirtothrips* sp. at 15 DAT. Spinetoram 12 SC® at 36 and 45 g a.i./ha was highly effective against the tobacco cutworm, *Spodoptera litura* (Fabricius, 1775) (Lepidoptera: Noctuidae) in minimizing leaf damages on common onion plants, *Allium cepa* L. (Asparagales: Amaryllidaceae) [33]. A similar trend in fall armyworm, *Spodoptera frugiperda* (J.E. Smith, 1797) (Lepidoptera: Noctuidae) larval mortality was observed at 48 h after spinetoram 120 SC® (130 mL/ha) application in maize plants, *Zea mays* L. (Poales: Poaceae) [35]. Field trial for four years showed that foliar applications of spinetoram at 13 g a.i./ha was effective to manage a complex of thrips including the tobacco thrips, *Frankliniella fusca* (Hinds, 1902) and the onion thrips, *Thrips tabaci* Lindeman, 1889 (Thysanoptera: Thripidae) infesting upland cotton seedlings, *Gossypium hirsutum* L. (Malvales: Malvaceae) [36].

Effectiveness of spinoteram against *S. semicanella* on *Eucalyptus* in field

Infestation of *S. semicanella* in the selected *Eucalyptus* spp. plantation was 100% prior to establish the insecticide treatments. Significant (P= 0.05) reduction of *S. semicanella* incidence was noticed in the spinetoram at 12 g a.i./ha treatment when compared to imidacloprid at 20 g a.i./ha treatment and control blocks. Spinetoram was greatly superior in minimizing the incidence of *S. semicanella* from 100 to 11% at 30 DAT. Standard check imidacloprid was significantly (P= 0.05) better than control but inferior to spinetoram. *Strepsicrates semicanella* incidence was 24% in imidacloprid treatment whereas in control it was 93% at 30 DAT (Figure 3).

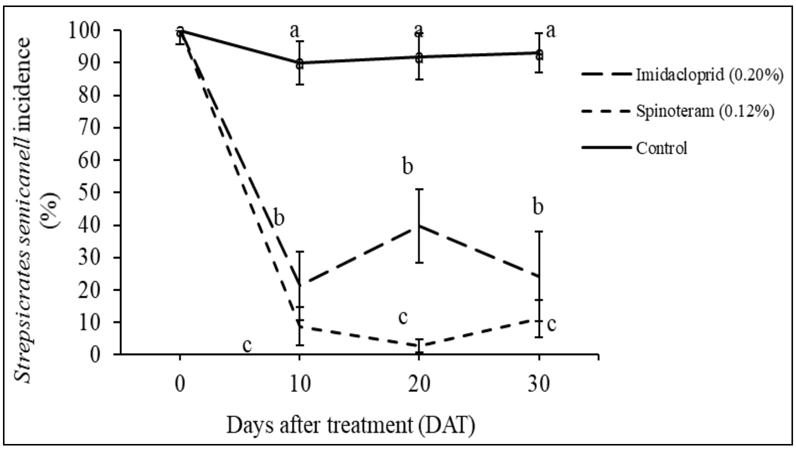

Fig 3: Incidence of leafroller, *Strepsicrates semicanella* (Lepidoptera: Tortricidae) on *Eucalyptus* spp. (Myrtaceae) in field to different insecticides. Bars with same letters are not significantly different at P= 0.05.

Spinetoram at 12 g a.i./ha was significantly (*P*= 0.05) superior in minimizing the severity of *S. semicanella* from 58 to 2.8% at 30 DAT (Figure 4). Severity of *S. semicanella* in imidacloprid treatment was significantly (*P*= 0.05) better than control but inferior to spinetoram. *Strepsicrates semicanella* severity was 7.5% in imidacloprid treatment whereas it was 54% in control at 30 DAT.

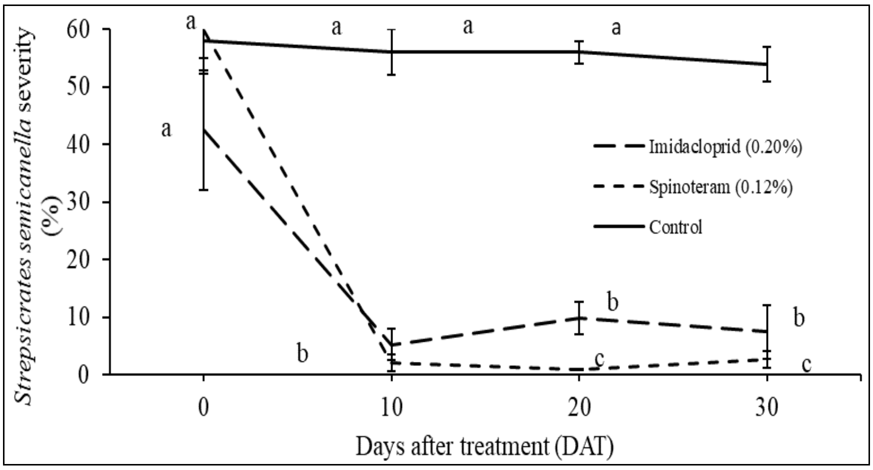

Fig 4: Severity of leafroller, *Strepsicrates semicanella* (Lepidoptera: Tortricidae) on *Eucalyptus* spp. (Myrtaceae) in field to different insecticides. Bars with same letters are not significantly different at *P*= 0.05.

Similarly, to *S. semicanella* in the current study, spinetoram was greatly effective against the oblique banded leafroller, *Choristoneura rosaceana* (Harris, 1841) (Lepidoptera: Tortricidae) in pome fruit (Rosales: Rosaceae) garden, also the resistance development was slower than to chlorantraniliprole insecticide [37]. Spinetoram (0.42 Kg/ha) provided long-lasting (seven days) control against all stages of both key pests of cranberries, *Vaccinium* sp. (Ericales: Ericaceae), the sparganothis fruitworm moth, *Sparganothis sulfureana* (Clemens, 1860) and the parallel-banded leafroller moth, *Choristoneura parallela* (Robinson, 1869) (Lepidoptera: Tortricidae) [38].

Spinetoram at two, five, seven, 10, and 12 g a.i./ha was significantly (*P*= 0.05) superior than control in reducing the *S. semicanella* infestation. Spinetoram at seven and 10 g a.i./ha was on par (*P*= 0.05) in reducing *S. semicanella* incidence at 30 DAT. Incidence of *S. semicanella* in untreated control was 89% at 30 DAT (Table 3). Spinetoram at 10 and 12 g a.i./ha was significantly (*P*= 0.05) on par and was superior to other treatments at 30 DAT.

Table 3: Leafroller, *Strepsicrates semicanella* (Lepidoptera: Tortricidae) incidence on *Eucalyptus* spp. (Myrtaceae) in field to different doses of spinetoram.

Treatments (g a.i./ha)	Incidence ± SD (%)			
	0 DAT	10 DAT	20 DAT	30 DAT
Spinetoram (2)	95.0 ± 6.9a	53.7 ± 22.4b	27.7 ± 10.6b	10.5 ± 7.9b
Spinetoram (5)	98.4 ± 3.6a	38.7 ± 10.9bc	18.9 ± 8.6bc	8.9 ± 8.8bc
Spinetoram (7)	94.3 ± 4.6a	34.0 ± 9.7c	21.1 ± 19.9bc	5.7 ± 6.2bcd
Spinetoram (10)	91.2 ± 9.5a	31.7 ± 5.4c	14.7 ± 7.9bc	2.4 ± 3.6d
Spinetoram (12)	95.1 ± 5.4a	34.8 ± 10.9c	13.6 ± 8.7c	4.0 ± 5.7cd
Control	91.0 ± 3.5a	82.0 ± 11.1a	91.0 ± 3.5a	89.4 ± 6.2a

Values in columns with same letters are not significantly different at *P*= 0.05. SD= standard deviation.

Data pertaining to *S. semicanella* severity at different doses of spinetoram is presented (Table 4). Mean *S. semicanella* severity inferred that spinetoram at two, five, seven, 10, and 12 g a.i./ha were significantly (*P*= 0.05) superior than control. It was observed that spinetoram at five, seven and 10 g a.i./ha were on par (*P*= 0.05) at 10 DAT compared to spinetoram at 2 g a.i./ha and untreated control. At 30 DAT all the tested doses of spinetoram were on par and statistically (*P*= 0.05) superior to untreated control (23%) (Table 4).

Table 4: Leafroller, *Strepsicrates semicanella* (Lepidoptera: Tortricidae) severity on *Eucalyptus* spp. (Myrtaceae) in field to different doses of spinetoram.

Treatments (g a.i./ha)	Severity (%) ± SD			
	0 DAT	10 DAT	20 DAT	30 DAT
Spinetoram (2)	30.9 ± 1.8a	14.5 ± 6.4b	6.9 ± 2.7b	3.3 ± 1.5b
Spinetoram (5)	31.1 ± 3.7a	10.5 ± 3.3bc	4.7 ± 2.1b	2.8 ± 2.1b
Spinetoram (7)	27.4 ± 2.6a	8.9 ± 2.9c	5.3 ± 5.0b	2.4 ± 1.2b
Spinetoram (10)	30.0 ± 5.9a	7.9 ± 1.4c	3.7 ± 2.0b	1.5 ± 0.7b
Spinetoram (12)	28.6 ± 2.5a	8.7 ± 2.7c	3.4 ± 2.2b	2.5 ± 0.7b
Control	29.0 ± 3.2a	24.7 ± 5.8a	28.8 ± 4.5a	23.4 ± 2.0a

Values in columns with same letters are not significantly different at *P*= 0.05. SD= standard deviation.

Spinetoram, evaluated in the current study, is suitable component of IPM programs that employ biological control agents [32]. In addition, spinetoram in recommended dosages does not cause phytotoxicity effects on treated plants [32, 33]. Field experiments were conducted and results revealed that application of spinetoram at 45 g a.i./ha showed low impact to coccinellid predators (Coleoptera) (9.6 and 5.5% reduction) of tomato ecosystem, *Solanum lycopersicum* L. (Solanales: Solanaceae) [39]. Spinetoram can be effectively used in IPM program against the western flower thrips, *Frankliniella occidentalis* Pergande, 1895 (Thysanoptera: Thripidae) by conserving the populations of the insidious flower bug, *Orius insidiosus* (Say, 1832) (Hemiptera: Anthocoridae) on pepper plants, *Pepper* L. (Piperales: Piperaceae) [40]. Spinetoram showed no significant effects on the honeybee, *Apis* L., 1758 (Hymenoptera: Apidae), domestic silk worm, *Bombyx mori* (Linnaeus, 1758) (Lepidoptera: Bombycidae) and other tested non-target organisms [41]. The spinosyn families of insecticides show greater selectivity toward target insects and lesser activity against many beneficial predators as well as mammals and other aquatic and avian animals when compared with many other insecticides [42].

Conclusion

Spinetoram is an effective molecule to be utilized in Forestry compliant with FSC (Forest Stewardship Council) certification. The effectiveness of spinetoram-based solution was 100% to *S. exigua* and 95% to *Scirtothrips* sp. at 15 days after treatment (DAT) in nursery and minimizing the severity of *S. semicanella* from 58 to 2.8% at 30 DAT in field. Results from the current study confirmed that spinetoram exhibited broad spectrum insecticidal activity. As there is also risk of development of resistance to the continuous use of same molecule, insecticide rotation program has to be emphasized for better management of these pests.

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